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COST OF RECYCLING WASTE MATERIAL FROM FAMILY HOUSING.(U)
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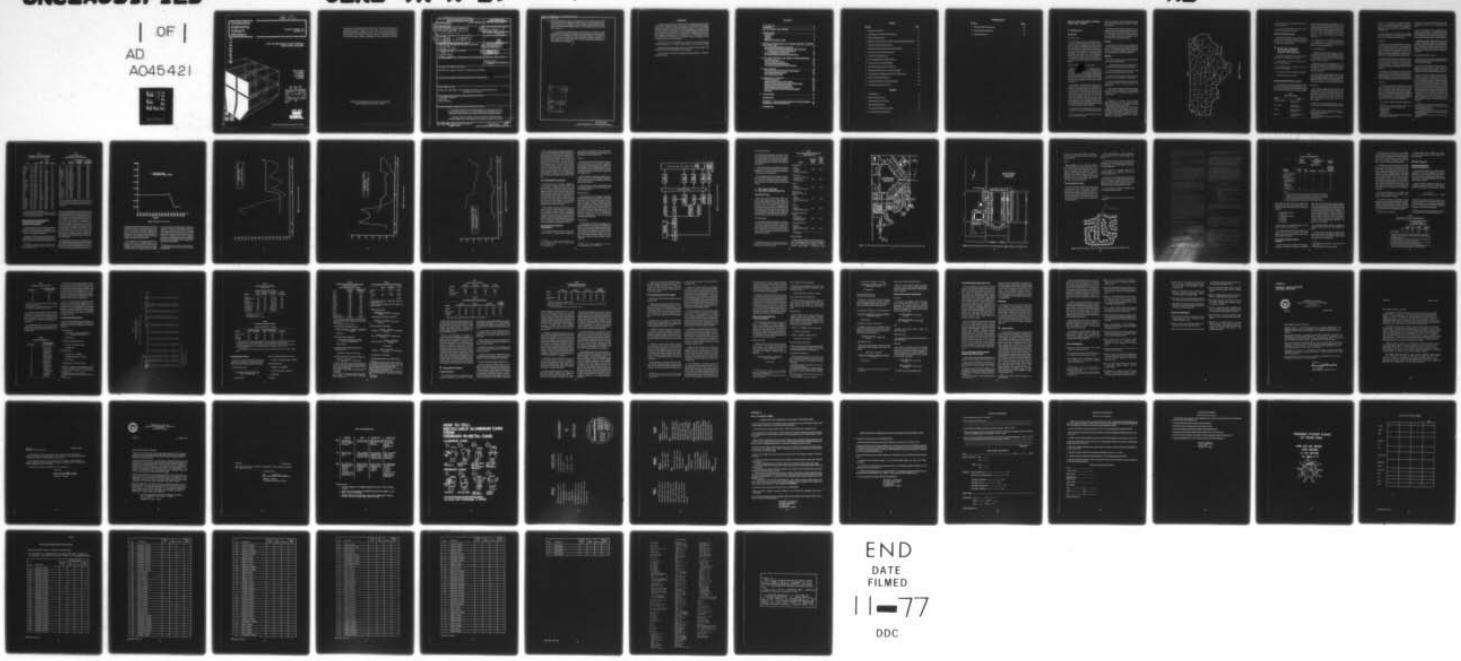

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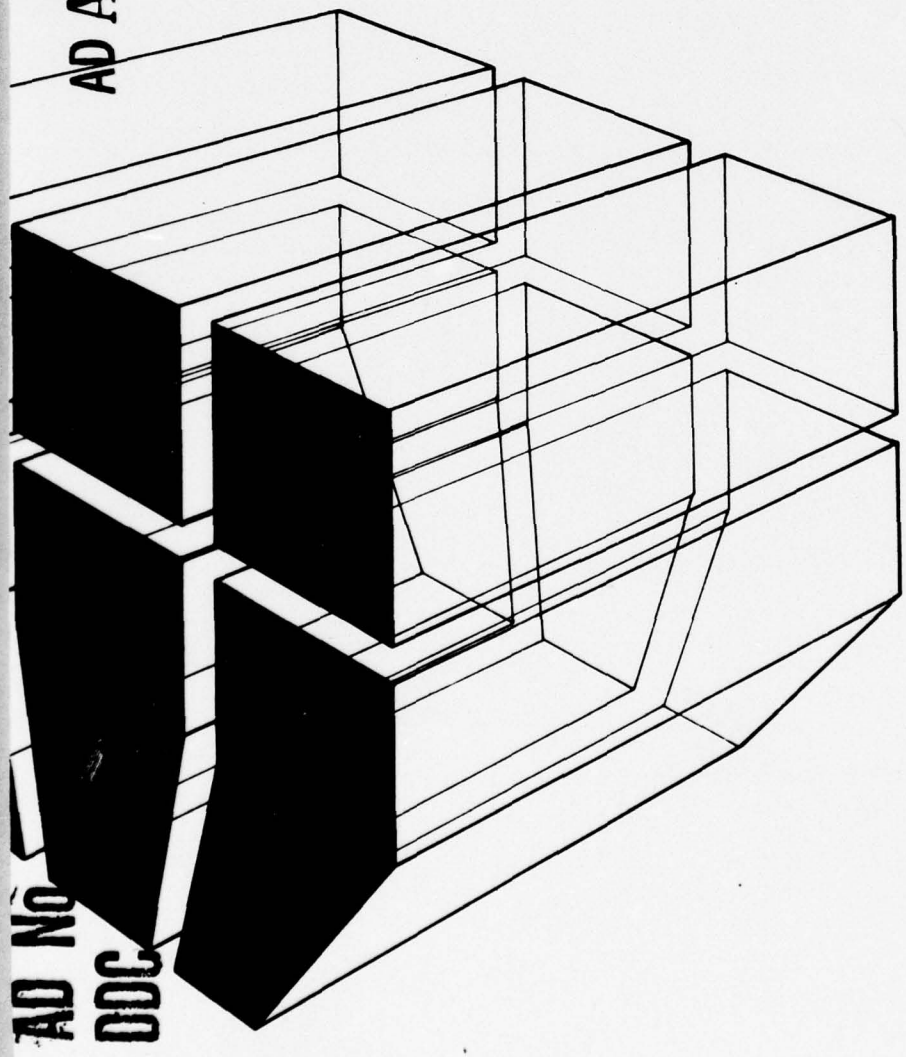
TECHNICAL REPORT N-29
September 1977

COST OF RECYCLING WASTE MATERIAL FROM FAMILY HOUSING



by R. E. Freeman
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1. REPORT NUMBER: CERL-TR-N-29	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): COST OF RECYCLING WASTE MATERIAL FROM FAMILY HOUSING.	5. TYPE OF REPORT & PERIOD COVERED: FINAL rept.
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): R. E. Freeman, B. A. Donahue, S. E. Kloster, G. W. Schanche, E. D. Smith	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: CONSTRUCTION ENGINEERING RESEARCH LABORATORY, P.O. Box 4005, Champaign, IL 61820	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 4A762720A896-T2-007
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: September 1977
	13. NUMBER OF PAGES: 51
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

solid waste recovery
recycling
family housing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this research was to determine the cost of recycling waste from a selected family housing area at Fort Bragg through source separation in order to evaluate the feasibility of solid waste recovery and recycling at a military installation.

This report presents (1) analysis of the waste volume and composition from the Normandy Heights area at Fort Bragg, (2) data showing the current cost of refuse

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collection and disposal in the Normandy Heights area, (3) a market analysis for recyclable material in the Fort Bragg area, and (4) a design for the recyclable material recovery strategy that was tested and the costs associated with this strategy, (5) participation rates of Normandy Heights residents, (6) waste reduction rates, and (7) collection labor data.

It was found that recycling by source separation could be cost-effective, could reduce the amount of refuse to be landfilled, and could decrease the number of weekly collections. It was established that military family housing refuse is comparable to that of the civilian sector and that military personnel are willing to participate in a source separation recycling program. The research indicated that experienced personnel should collect recyclables.

FOREWORD

This project was performed for the Directorate of Facilities Engineering, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task T2, "Pollution Control Technology"; Work Unit 007, "Solid Waste Management for Military Facilities." The research was conducted by the Environmental Engineering Team (ENE), Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (CERL). The applicable QCR is 1.03.006(4). Mr. A. P. Norwood was the OCE Technical Monitor. Mr. B. Donahue was the CERL Principal Investigator, and Mr. G. Schanche was the Associate Investigator.

The authors wish to acknowledge the assistance of the Stanford Research Institute and of COL C. J. Cox, COL E. N. Willis, and Mr. B. Anderson of Fort Bragg.

Administrative support provided by Mr. W. J. Mikucki, Chief of CERL-ENE, and Dr. R. K. Jain, Chief of CERL-EN, is acknowledged.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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COST OF RECYCLING WASTE MATERIAL FROM FAMILY HOUSING

1 INTRODUCTION

Background

Problem Statement

In consonance with U.S. Environmental Protection Agency (USEPA) guidelines,[1] the Department of Defense (DOD) has established a resource recovery and recycling policy, DOD Directive 4165.60, *Solid Waste Management-Collection, Disposal, Resource Recovery and Recycling Program.* Since all military installations must respond to the requirements of this Directive, the Office of the Chief of Engineers (OCE) initiated a project to study the economics of recovering and recycling solid waste materials in conjunction with refuse collection at an Army installation.

Selection of Fort Bragg, NC, as a Test Site

Personnel at Fort Bragg, NC, volunteered that installation [illegible] of a 3-month recycling demonstration [illegible] family housing was chosen for the study because environmental legislation dealing with disposal of solid wastes from family housing is pending, and it was necessary to determine if recycling the types of wastes generated in these areas would be cost effective.

Fort Bragg is approximately 110 miles east of Charlotte, NC, and 70 miles south of Raleigh, NC, adjacent to Fayetteville (Figure 1). It is the site of the U.S. Army 82nd Airborne Division, the U.S. Army Special Forces, the Airborne Communications and Electronics Test Group of the U.S. Army Development and Readiness Command, the U.S. Army Combat Development Group, the U.S. Army Parachute Team, and the U.S. Continental Army Command Intelligence Center (CONTIC). Pope Air Force Base (AFB) is adjacent to Fort Bragg, and its mission is to support the 82nd Airborne Division.

Data provided by Fort Bragg show that the combined solid waste stream for Fort Bragg and nearby Pope AFB resembles mixed residential/municipal refuse equaling approximately 135 TPD_s (tons/day, 5 days/week).[2]

Fort Bragg currently disposes of refuse at an installation-owned and -operated landfill. Refuse is collected by both installation personnel and contractor 5 days/week using a fleet of front-loader and rear-hoist collection vehicles. The landfill is now in the second year of a projected 20-year life.

Purpose

The purpose of this research was to determine the cost of recycling waste from a selected family housing area at Fort Bragg through source separation* in order to evaluate the feasibility of solid waste recovery and recycling at a military installation.

Approach

The cost of recycling wastes in family housing areas was determined as follows:

1. A family housing area at Fort Bragg was selected based on the criteria discussed in Chapter 3.

2. The refuse generation rates and refuse composition in the selected area were determined.

3. The cost of existing refuse collection and disposal services in the selected area was determined.

4. The cost of refuse collection and disposal in the selected area during the recycling experiment was determined.

5. The cost of recycling in the family housing area was determined by assessing the cost of extra storage containers, collection, processing, marketing, and public relations.

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[1] *Code of Federal Regulations,* 40 CFR 244, 245, and 246 (General Services Administration, 1976).

[2] S. Hathaway and J. Woodyard, *Technical Evaluation Study—Solid Waste as a Fuel at Fort Bragg, NC,* Technical Report E-95/ADA034416 (U.S. Army Construction Engineering Research Laboratory [CERL], December 1976).

*Source separation or source segregation is the setting aside of recyclable waste materials (such as paper, glass, and metal containers) at their point of generation (the home, office, or other place of business) by the generator. This separation is followed by transportation of the recyclable materials from their point of generation to a market, e.g., a processing center, a secondary materials dealer, or a manufacturer.

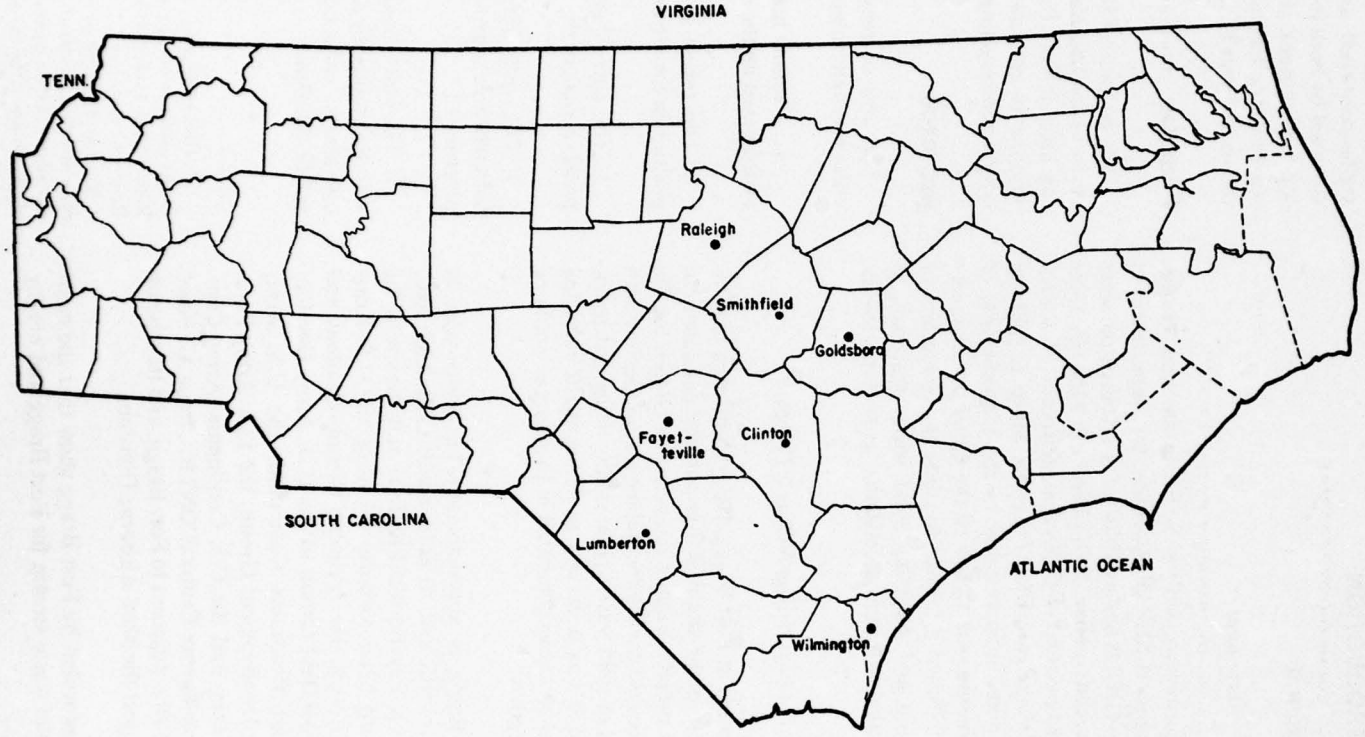

Figure 1. Fort Bragg area.

6. The tangible and intangible return from recycling was determined.

7. A system for optimizing recycling in family housing at Fort Bragg was identified.

Mode of Technology Transfer

This information may be used as technical information by OCE in finalizing AR 420-47, *Solid Waste Management*, by providing material for Chapter 5, "Resource Recovery/Recycling."

2 DESIGN AND EVALUATION OF A REFUSE DISPOSAL PROGRAM WITH RECYCLING

The design of a recyclable material recovery program requires consideration of four aspects:

1. What materials should be recycled (this requires a market analysis)

2. The public relations program necessary to motivate the participants

3. The need for source segregation by household

4. Recyclable materials collection.

Determining What Materials to Recycle

The economics of recycling necessitated that the portion of the waste stream to be segregated by study participants be limited to materials having a market in or around Fort Bragg. Table 1 lists the recyclable material and its associated viable market. For this study, all potential recyclables were included in an integrated system. This seemed to be a more economically feasible method because certain aspects of the program, such as public relations and collection, could be conducted simultaneously for several materials as easily as they could for each material separately.

Table 1

Markets for Recyclables

Material	Market
Ferrous and Bi-Metals	American Can Co. Greensboro, NC
Glass—Mixed	Owens—Illinois Winston-Salem, NC
Aluminum	Reynolds Aluminum Co. Richmond, VA
Newsprint	Paper Stock Dealers, Inc. Fayetteville, NC

To determine the cost of material recycling by source segregation, it is essential that accurate and up-to-date information be accumulated about viable markets for the recycled materials.

Ferrous and Bi-Metals

Nationally, approximately 50 percent of the ferrous discards are cans, while the remainder consists of appliances (16 percent), and miscellaneous items such as hardware, metal castings, and nondescript pieces of metal (33 percent).[3]

Scrap steel cans in the Fort Bragg area can be marketed to the steel and detinning industries. During this study, American Can Company of Greensboro, NC, was purchasing ferrous metals and bimetals for detinning.

The 1974 national market value for can scrap for detinning ranged from $30 to $100 per ton, depending on geographical location and the quality of the material.[4] During 1974, Fort Bragg received approximately $10 per ton (F.O.B.* Greensboro, NC).

Mixed Glass

Glass comprises approximately 10 percent[5] of the municipal waste stream. Containers represent the major portion of glass found in solid waste; approximately 60 percent of these are made of flint (or clear) glass. The remainder is split between amber glass used for beer bottles and green glass used for wine and soft drinks.

There are two major potential markets for recovered waste glass: as cullet for making new bottles,

[3] *Resource Recovery Plant Implementation: Guides for Municipal Officials, Markets*, SW-157.3 (U.S. Environmental Protection Agency, [USEPA], 1976).

[4] USEPA SW-157.3.

*Fee on board—the market price paid at the point of delivery.

[5] USEPA SW-157-3.

and as a raw material for making secondary products (i.e., highway paving material, foamed insulation, construction materials). Fort Bragg sells glass cullet to Owens-Illinois Corporation of Winston-Salem, NC.

In 1974, waste glass had a market value ranging from $15 to $25 per ton, F.O.B. the plant.[6] During this period, Fort Bragg received $20 per ton.

Aluminum

Aluminum constitutes approximately 0.7 percent of the municipal waste stream.[7] Approximately half of the aluminum discards are cans, one-third are foils, and the remainder largely parts from major appliances.[8] Aluminum composition, however, varies significantly from one community to another due to differences in aluminum beverage can distribution.

Nationally, aluminum scrap constituted 27 percent of the national aluminum production in 1973. Of the scrap used, 60 percent was consumed by secondary smelters, 17 percent by primary producers, and the remainder by aluminum fabricators and foundries.[9]

Nationwide, the average price per pound of aluminum scrap delivered to aluminum companies and to brewers was $0.15.[10] The F.O.B. Fort Bragg price in 1974 for aluminum scrap was $0.12 per pound paid by Reynolds Aluminum Company in Richmond, VA.

Newsprint

In 1974, approximately 3.5 million tons (3.15 million t) of newsprint were produced in the United States, of which 3.3 million tons (2.97 million t) were used in the nation's daily and weekly newspapers. Approximately 200,000 tons (180,000 t) were shipped overseas. In addition, 7.4 million tons (6.60 million t) were imported. Total U.S, consumption of newsprint in 1974 was 10.7 million tons (6.66 million t).[11]

On a national average, newsprint comprises approximately 19 percent of discarded paper and approximately 6 percent of total municipal solid waste.[12]

Uses[13] for newsprint are in combination boxboard, printing, and other white paper grades and in building products such as insulation and soil pipe. Also, the technical and economic feasibility of recycling newspapers into newsprint is well established.[14]

Generalizations concerning the market price for newsprint are difficult to make because of regional variations. Paper Stock Dealers, Inc., of Fayetteville, NC, purchased dry, bundled newsprint from Fort Bragg at 60 percent of the Chicago F.O.B. price. This proprietor paid $14/ton F.O.B. Fort Bragg in late 1974.

Recyclable Material Price Trends

Table 2 lists the prices for recyclable materials in the Fort Bragg area in dollars per pound for 1973 to 1976 F.O.B. at Fort Bragg.

Table 3 lists the prices for recyclable materials in dollars per pound, F.O.B., for 1974 to 1976, at Chicago, Cincinnati, and Birmingham. This list was compiled from data presented in *Recycling Today*.[15]

Figures 2 through 5 compare Fort Bragg area market trends vs. the price trends listed in Table 2 for glass, aluminum, ferrous/bi-metals and newsprint. These figures readily show that Fort Bragg's recycling market prices and the "national" recycling prices have fluctuated dramatically from 1974 to 1976. In the Fort Bragg area, prices for newsprint and bulk glass have decreased, while ferrous/bi-metal and aluminum prices have increased. The figures also show that Fort Bragg area market prices for aluminum, ferrous scrap, and newsprint do not correspond with the market prices given for the closest national market. These discrepancies are caused by factors which are not within the scope of this report.

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[6] *Resource Recovery Plant Implementation: Guides for Municipal Officials, Markets*, SW-157.3 (USEPA, 1976).

[7] USEPA SW-157.3.

[8] USEPA SW-157-3.

[9] USEPA SW-157.3.

[10] USEPA SW-157.3.

[11] *Waste Paper Recycling* (American Paper Institute, Inc., Paper Stock Conservation Committee, 1975).

[12] *Resource Recovery and Utilization*, ASTM Special Technical Publication 592, H. Alter and E. Harowitz, eds. (American Society for Testing and Materials, 1975).

[13] *Resource Recovery and Utilization.*

[14] W. Franklin, *Paper Recycling—The Art of the Possible 1970-1985* (Midwest Research Institute for the Solid Waste Council of the Paper Industry, 1973).

[15] *Recycling Today*, Vol 12, No. 6, to Vol 14, No. 3 (June 1974 to March 1976).

Table 2

Fort Bragg Area—Recyclable Material Prices*
(Dollars per Pound, F.O.B. Fort Bragg)

Date		Newsprint	Mixed Glass	Ferrous and Bi-Metal	Aluminum
October	1973	0.0058	0.01	n.a.	n.a.
November	1973	0.0062	0.01	n.a.	n.a.
December	1973	0.0256	0.01	n.a.	n.a.
January	1974	0.0199	0.01	0.0033	n.a.
March	1974	0.0175	0.0115	0.003	n.a.
April	1974	0.0175	0.01	0.003	n.a.
May	1974	0.0175	0.01	0.005	n.a.
June	1974	0.024	0.01	0.005	0.12
July	1974	0.01	0.01	0.005	0.12
August	1974	0.01	0.01	0.005	0.12
September	1974	0.009	0.01	0.005	0.12
October	1974	0.01	0.01	0.005	0.12
November	1974	0.0082	0.01	0.005	0.12
December	1974	0.006	0.01	0.0033	0.12
January	1975	0.006	0.01	0.0033	0.12
February	1975	0.006	0.01	0.0033	0.12
March	1975	0.006	0.01	0.0033	0.16
April	1975	0.006	0.01	0.005	0.16
May	1975	0.006	0.01	0.005	0.16
June	1975	0.007	0.0117	0.005	0.16
July	1975	0.007	0.01	0.005	0.16
August	1975	0.007	0.0082	0.0081	0.16
September	1975	0.005	0.0056	0.0081	0.16
October	1975	0.01	0.01	0.005	0.16
November	1975	0.01	0.01	0.005	0.16
December	1975	0.01	0.01	0.005	0.16
January	1976	0.01	0.01	0.005	0.16
February	1976	0.01	0.01	0.005	0.16
March	1976	0.01	0.01	0.005	0.17

n.a. = no market price knowledge available.

*Personal communication of Bruce Anderson, Sanitation Branch Chief, Fort Bragg, with Robert E. Freeman, Stanford Research Institute (SRI), (December 1975).

Table 3

Recyclable Material Prices
(Dollars per pound, F.O.B., City Indicated)

Date		Newsprint (Chicago)	Mixed Aluminum Clippings (Cincinnati)	Scrap Iron No. 2 Bundles (Birmingham)
June	1974	0.013	0.215	0.026
July	1974	0.010	0.235	0.026
August	1974	0.010	0.235	0.025
September	1974	0.007	0.205	0.025
October	1974	0.004	0.185	0.025
November	1974	Nominal*	0.165	0.025
December	1974	Nominal	0.125	0.019
January	1975	Nominal	0.105	0.019
February	1975	Nominal	0.105	0.019
March	1975	Nominal	0.125	0.019
April	1975	Nominal	0.135	0.019
May	1975	Nominal	0.125	0.018
June	1975	Nominal	0.115	0.017
July	1975	Nominal	0.115	0.014
August	1975	Nominal	0.145	0.016
September	1975	Nominal	0.145	0.016
October	1975	0.003	0.135	0.016
November	1975	0.003	0.125	0.016
December	1975	0.003	0.125	0.016
January	1976	0.006	0.125	0.019
February	1976	0.006	0.135	0.021
March	1976	0.009	0.175	0.023

*Because of depressed conditions in the paper stock market, and in view of the almost total lack of demand for all grades, it is virtually impossible to pinpoint dollar value to waste paper at the present time.

Determination of the Public Relations Program Necessary to Motivate the Test Area Participants

Public education at the outset of this project and during the collection phase was considered to be crucial in order to increase public participation in the voluntary source segregation program.

According to the EPA publication PB-239 775,[16] public relations "at the onset and during a separate collection program has been found necessary to attain and retain participation. Announcements of the program should precede the implementation date by a month or more and outline the program goals, provide rationale for separate collection, present collection schedules, etc. During the interim period between initial announcement and implementation, continual reminders should be made through the local media (articles in newspapers, spot announcements on radio and television). In addition, notices in utility billings, printed door knob hangers, and announcements made to/by local civic/service groups are often used for initial and on-going publicity purposes." Appendix A shows the public relations materials used during the demonstration project at Fort Bragg.

Announcements were sent to test area residents in early April explaining the project and alerting them to their future anticipated participation in this program. Later in April, a second letter was sent to the test area residents supplying details about the source

[16]SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974).

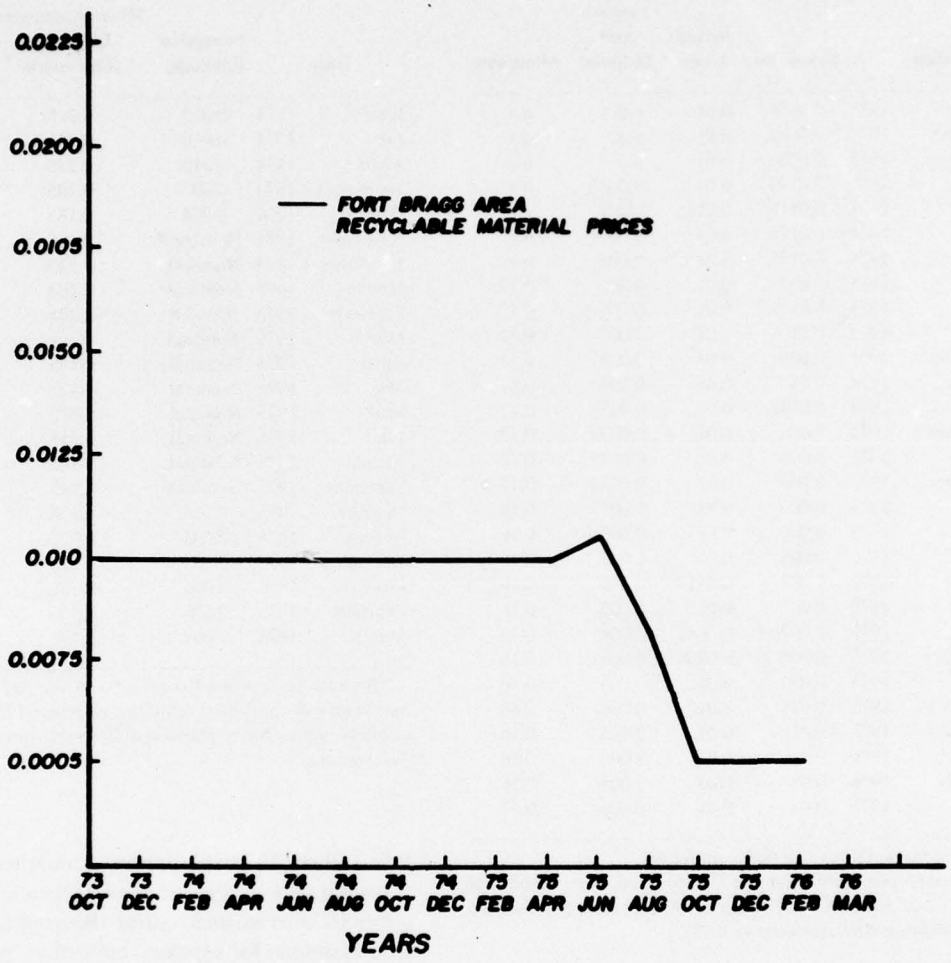

Figure 2. Bulk glass market trends.

segregation program (see Appendix A). Then, in late April, Stanford Research Institute (SRI) and CERL personnel answered the participants' questions and showed a short film on recycling. Additional announcements were delivered to each household (see Appendix A), and reminders appeared in the local newspaper during the collection period.

This investigation did not acquire adequate information about the cost of publicity efforts at Fort Bragg, but it was assumed that the costs would approximate those of other case study locations. (Data accumulated from 11 separate collection recycling studies are published in an EPA report,[17] which cites a range of 1 to 33 cents per household as the cost for initial public relations.) Costs for the Fort Bragg study included letters (flyers) mailed to the 163 study participants, postage, envelopes, paper, and preparation time. Although the cost for maintaining appropriate on-going publicity efforts is site-specific, this study will use the high end of the range cited by the EPA ($.33/initial effort).

[17]SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid: Waste Separate Collection Studies*, PB-239-775 (USEPA, 1974).

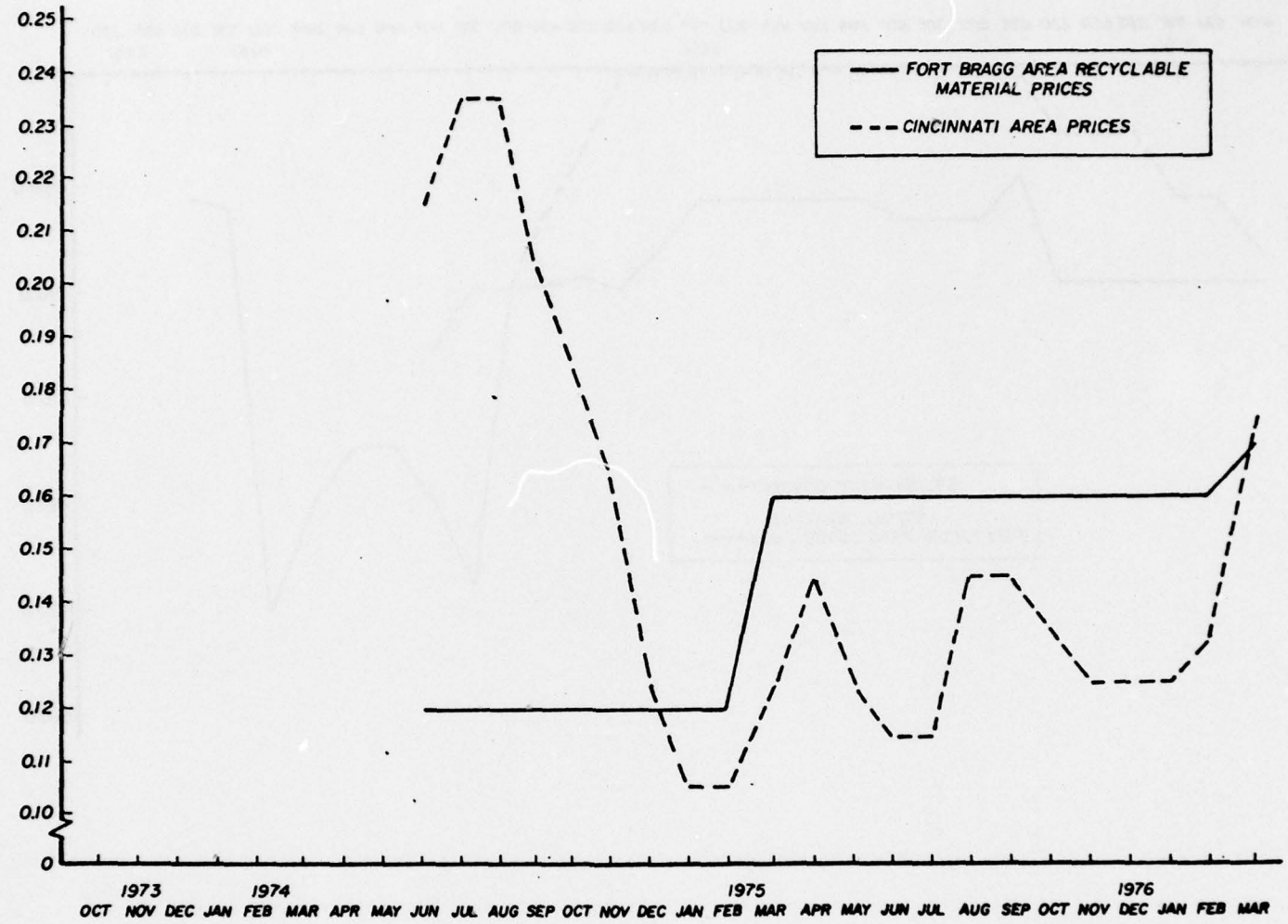

Figure 3. Aluminum market price trends.

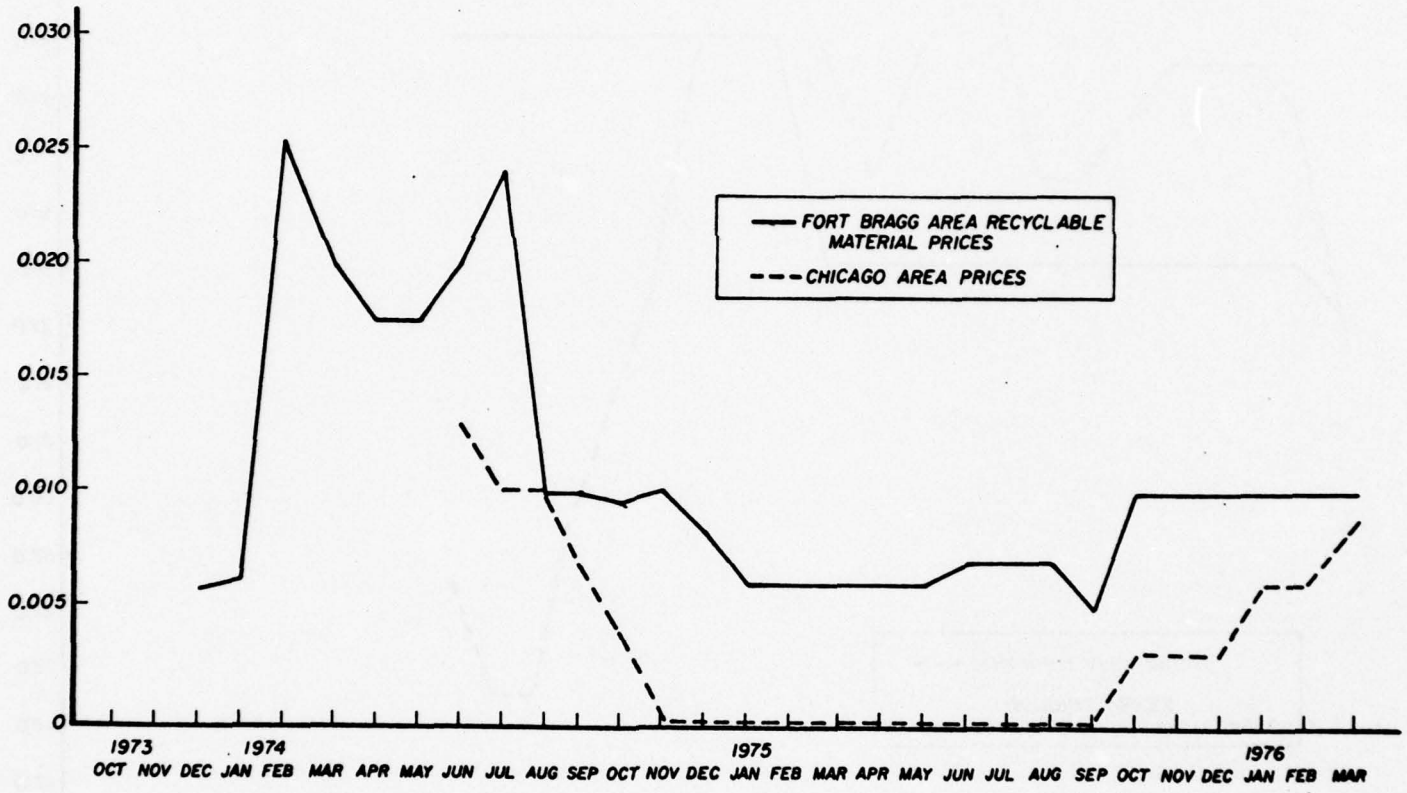

Figure 4. Newsprint market trends.

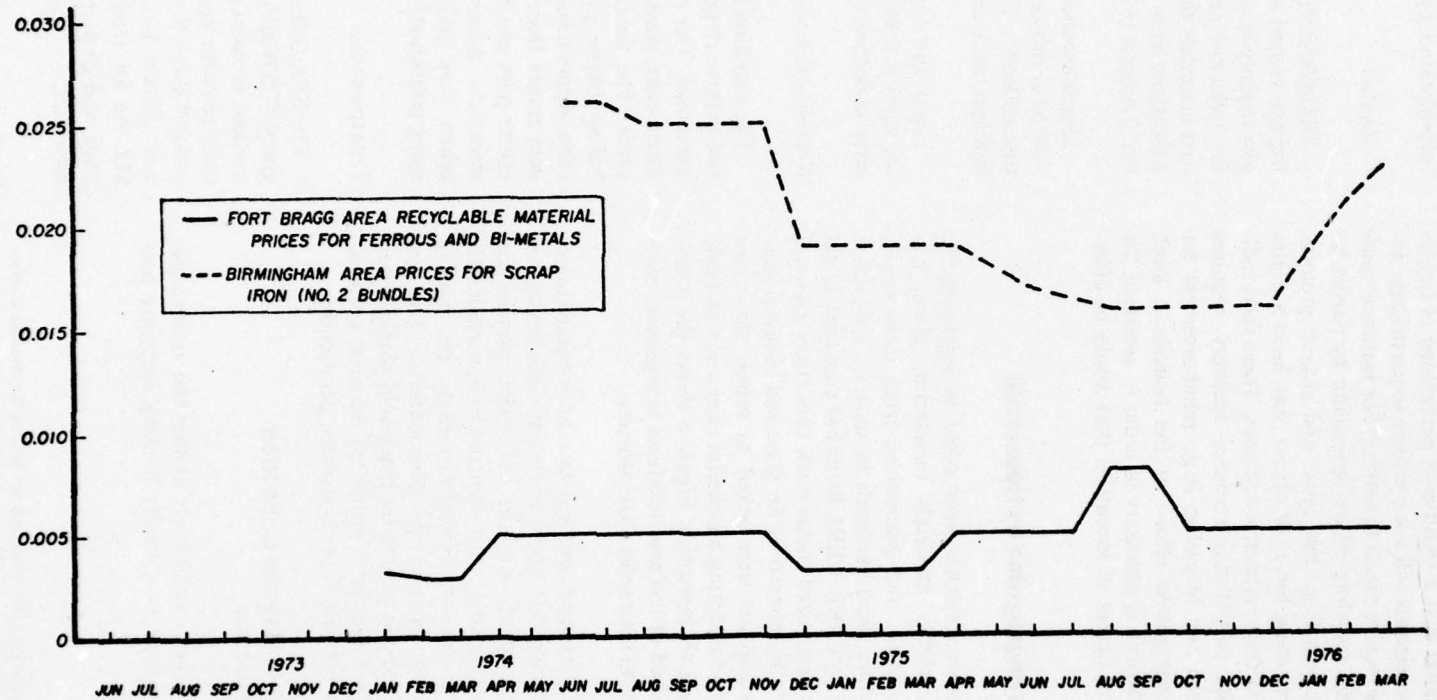

Figure 5. Ferrous/bi-metal market price trends.

While continuing public relations programs have been proved empirically to be highly motivating, evidence exists that a significant percentage of household participants will not continue to participate unless they receive direct benefits.[18] For instance, most successful recycling efforts are made by particular organizations (e.g., boy scout and church groups). The motivating force, of course, has been a dollar return for their respective activities. These facts indicate that substantial resource recovery requires motivation and incentives (e.g., reimbursement for refuse segregation effort) at the household level. More research is necessary in order to ascertain the types and degree of incentives that would be effective.

Source Segregation by Household

Test area residents were asked to segregate the four recyclable materials (newsprint, glass, ferrous/bi-metals, and aluminum) from their wastes and to store these materials in separate containers supplied by CERL. CERL furnished standard 32-gal (118.4-*l*) galvanized metal trash cans (from General Services Administration) for glass and bi-metal storage. Participants were asked to supply their own containers for storing aluminum cans and to bundle and secure all newsprint. Figure 6 shows the activities required of test area residents to segregate recyclables from their solid waste streams.

CERL personnel reviewed current literature to develop a factor that would represent costs associated with participant activities. Material preparation costs are defined as costs incurred by households for supplies or resources (water, electricity, etc.) used to segregate and prepare recyclable materials. This cost does not include a value for household participation time. SCS Engineers[19] estimated material preparation costs to be $0.02 per household per month.

Recyclable Material Collection Considerations

This section qualitatively defines the various elements involved in a family housing recycling program, discusses the information necessary for interpreting the Fort Bragg study, and extrapolates the information for use at other locations.

Collection

SRI determined the optimum collection route during the second site visit in April 1976. Appendix B gives examples of data collection forms completed by the collection crews. SRI determined that the recycled materials should be collected every 4 to 5 weeks; collections were made on 1 June 1976, 6 July 1976, and 3 August 1976.

Separate collection of recyclable material was considered a sub-system of the ongoing residential refuse collection system and required the use of independent truck and crew.

Labor and truck use data were gathered during the study period and used to calculate recyclable material collection costs.

Recycling Center

The recycling center at Fort Bragg is operated by two to three civilian personnel and five to six military personnel. The center processes aluminum and bi-metal cans, glass, cardboard, newspapers, and IBM cards. The facility is equipped for shredding and baling paper products and shredding aluminum cans. Approximately 50 percent of the center's business comes from county fund-raising projects. The center pays one-half the market value for recyclable materials. Accurate cost data for operating this center were unobtainable, so costs were estimated using published information.

Transportation

The EPA Office of Solid Waste Management Programs (OSWMP) has developed recommended estimations to assist planners, designers, and officials in their resource recovery decisions. OSWMP's publication[20] states that transportation costs (in 1975 dollars) should be assumed to be $6/ton for glass, $12/ton for ferrous materials, $20/ton for aluminum, and 25 percent of expected revenues for other materials.

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[18]SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974).

[19]SCS Engineers, Inc.

[20]*Resource Recovery Plant Implementation: Guides for Municipal Officials*, SW-157.3 (USEPA, 1976).

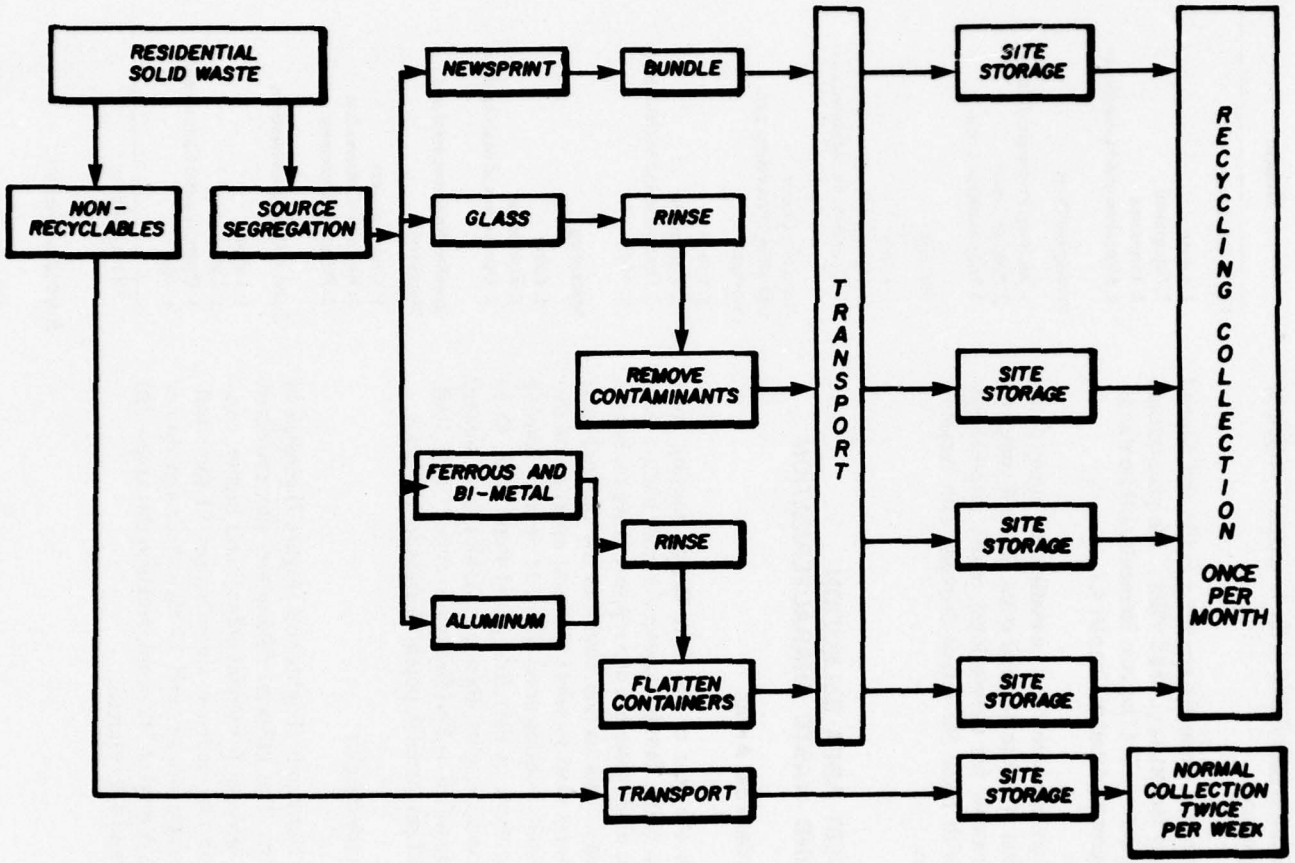

Figure 6. Source segregation of solid waste.

Landfill Considerations

One advantage of recycling is a decrease in landfill operation and maintenance costs (labor, equipment, and facilities) due to decreased waste volumes. Associated with this is an increase in the landfill site amortization period due to the lower-than-anticipated usage rate.

These cost elements are site-specific and depend on many factors (e.g., land values, site preparation, equipment, etc.). (The cost elements will be discussed in greater detail in Chapter 4.)

Certain elements must be considered in any determination of refuse disposal costs. Table 4 compares the elements for conventional refuse disposal systems with those for refuse disposal with recycling systems.

Table 4

Elements to Be Considered in the Determination of Refuse Disposal Costs

Element	Conventional Refuse Disposal	Refuse Disposal With Recycling
Public Relations		
1. Labor 2. Equipment 3. Incentives 4. Operation and Maintenance	Debit	Debit
Participant Costs		
1. Material Preparation Costs 2. Storage Costs 3. Inconvenience Costs	Debit	Debit
Collection		
1. Labor 2. Equipment 3. Operation and Maintenance	Debit	Debit
Recycling Center (Handling, Processing, and Storage)		
1. Labor 2. Equipment 3. Operation and Maintenance 4. Site	N/A*	Debit
Marketing		
1. Labor 2. Equipment 3. Operation and Maintenance	N/A	Debit
Benefits (Environmental and Monetary)		
1. Cash Recovery 2. Resource Conservation 3. Pollution Abatement	Debit	Asset
Land-Filling Considerations		
1. Labor 2. Equipment 3. Operation and Maintenance 4. Site	Debit	Asset

*Not applicable.

3 TEST AREA SELECTION AND WASTE CHARACTERIZATION

Potential Test Areas

Both the size of the Fort Bragg housing community (4216 family quarters[21]) and budget constraints made selection of a representative study area necessary. This section describes the rationale and procedures used to select the most appropriate discrete family housing area. Of the 11 military housing developments at Fort Bragg and Pope AFB, three (Normandy Heights, Bastogne Gables, and Bataan) were identified by Fort Bragg personnel, CERL staff, and SRI personnel as potential areas for the study.

Normandy Heights

The Normandy Heights area (Figure 7) consists of 163 units. The 145-acre (58-hectare) site, restricted to the ranks of lieutenant colonel and higher, comprises 18 four-bedroom single houses, 91 three-bedroom single houses, and 27 three-bedroom duplex houses. A total of 742 people reside in this area—320 adults and 422 children.

Bastogne Gables

Noncommissioned officers reside in the 128 quarters in the Bastogne Gables housing area (Figure 8). The 46-acre (18-hectare) site consists of 89 three-bedroom single houses, 7 two-bedroom single

[21]Personal communication of R. C. Reynolds, Chief of Family Housing Branch, Fort Bragg, with Robert Freeman, Stanford Research Institute (SRI) (5 December 1975).

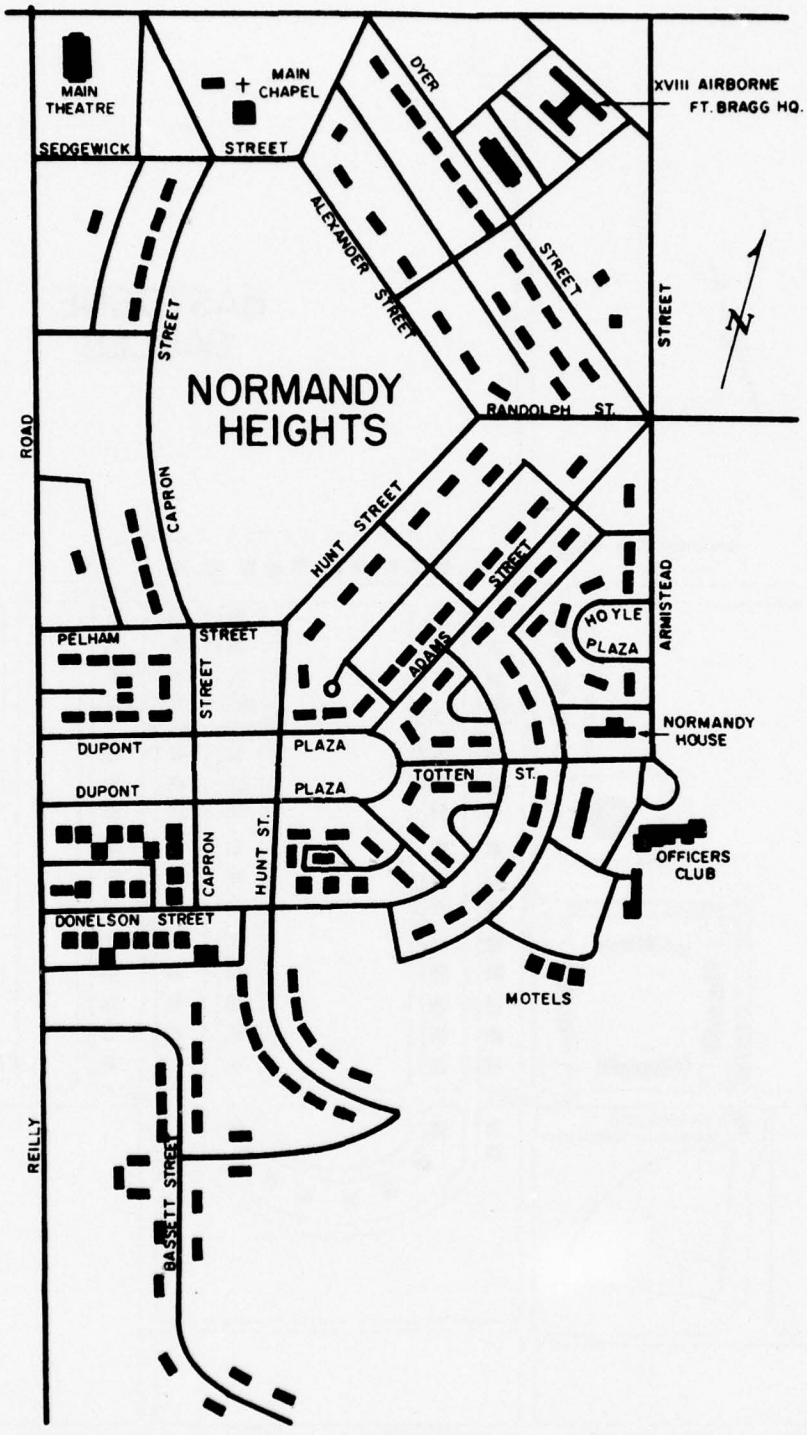

Figure 7. Normandy Heights housing area. (From Fort Bragg, NC, telephone directory, November 1974.)

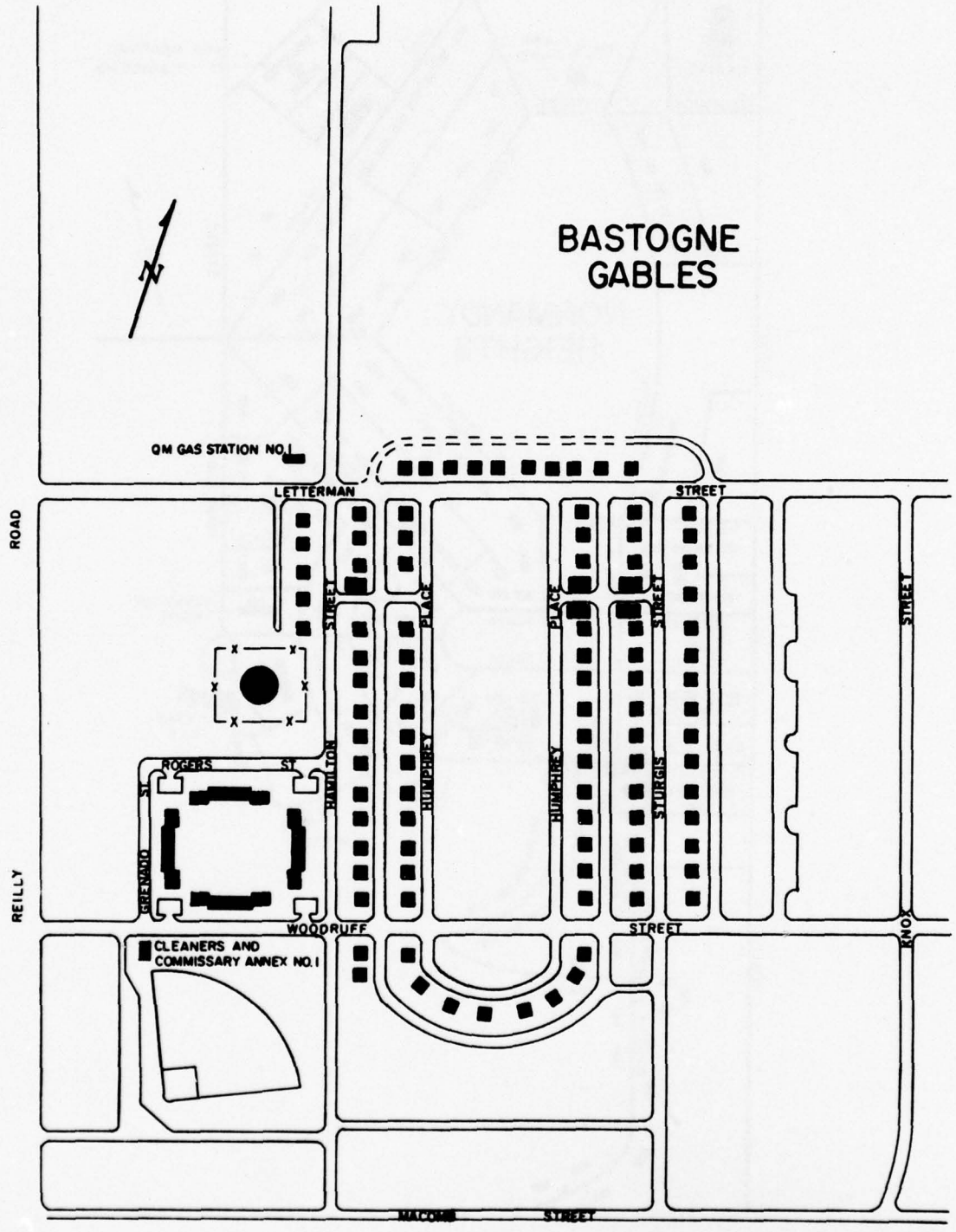

Figure 8. Bastogne Gables housing area. (From Fort Bragg, NC, telephone directory, November 1974.)

houses, and 4 eight-unit apartment buildings. A total of 527 people reside in this area—264 adults and 263 children.

Bataan

Bataan (Figure 9) is one of the newer housing areas at Fort Bragg. The 156 quarters were built in late 1974 for senior noncommissioned officers. The 43-acre (17-hectare) site comprises 49 four-unit apartment buildings having both three- and four-bedroom units. Unlike Normandy Heights and Bastogne Gables, all units in Bataan have garbage disposals. A total of 758 people reside in this area—312 adults and 446 children.

Test Area Selection Criteria

The next step was to choose the most appropriate housing area or areas for testing within the selected general testing area. A manageable number of households in a defined grouping from which to collect data representative of the entire community was deemed most desirable. The following criteria were used as guidance for choosing the most appropriate family housing area.

1. Waste characteristics or factors influencing waste generation from the family housing community.

The problem of selecting a group of households representative of the community was analyzed. Factors influencing waste characteristics (composition and weight) included:

a. Age Group. It is generally believed that younger families tend to generate more waste of lower recyclable values.[22]

b. Economic Level. Higher-income families tend to generate refuse with a larger amount of recyclables, and therefore a higher market value; i.e., a higher percentage of paper products and metals (especially aluminum) and less garbage and trash.

2. Factors related to expected compliance with source segregation instructions.

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[22] *Recycling Today*, Vol 12, No. 6, to Vol 14, No. 3 (June 1974 to March 1976).

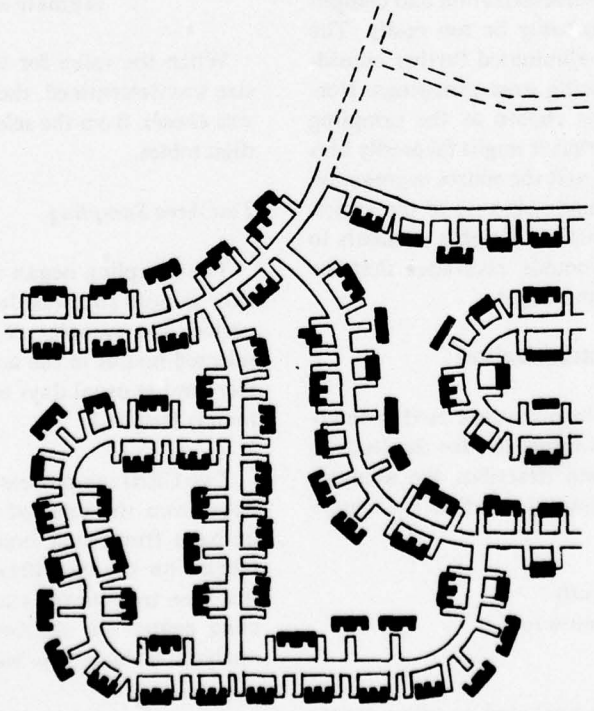

Figure 9. Bataan housing area. (From Fort Bragg, NC, telephone directory, November 1974).

a. Participation. Generally, the greatest participation in recycling projects is among people with the most education, and the lowest among people with the least education.

b. Effectiveness. It was assumed that continued compliance would be greater with higher-ranking officers' families.

3. Factors influencing study costs. Minimizing study costs was an important consideration in selecting the household sample. The principal factor here was the sample's physical layout. The sample should be physically isolated from other housing areas to decrease the operational problems and the costs associated with waste collection during the study.

Using these criteria, eight potential study sites were selected from the three housing areas (see Table 5). To prevent bias in the ultimate choice of a study area, equal weights were assigned to all of the rating criteria. Each potential site was then ranked according to how it met the criteria.

As indicated in Table 5, it appeared that combined sampling from Normandy Heights and Bastogne Gables would produce the most representative data on waste characterization and compliance tests, but would probably be too costly. The concern over study costs eliminated further consideration of any multi-housing area groupings. Normandy Heights alone was chosen as the sampling area, despite indications that it might favorably bias both the characterization and the source segregation tests. This decision was made because of the anticipated willingness of Normandy Heights residents to participate, and the reasonable assurance that the study costs would be within budget.

Test Area Refuse Characterization

This section describes the procedure used to determine a statistically valid sample size for the test site waste characterization and describes the analyses used to characterize the sampled refuse by volume and composition.

Determination of Statistically Significant Number of Houses to Be Sampled

A statistical procedure was used to select representative households for sampling the average volume, weight, and composition of waste generated in a typical family housing area.

Sample size and number of observations required to yield statistically meaningful data were relatively unaffected by the housing area(s) chosen; i.e., the number of households and observations could be determined independently of the sample test area.

Eq 1, derived from Cochran,[23] was used to estimate the statistically valid sample size (at the 90 percent confidence level) required for waste characterization in the selected area. This formula calculates error intervals ($\triangle$) for the average of a sample of n units taken from a population of N units within a community. The sample size n can be found with this equation:

$$\triangle_{\bar{x}} = \sqrt{(\sigma_x^2/n)\left(\frac{N-n}{N}\right)} \cdot T_{90,n-1} \qquad [Eq\ 1]$$

where $\triangle_{\bar{x}}$ = error interval, percent of the mean $\bar{x}$
σ_x^2 = sample variation = (sample standard deviation)^2
n = proposed number of housing units to be samples
N = 163 housing units total
T = "T" statistic for 90 percent confidence estimate and n − 1 sample size.

When the value for the statistically valid sample size was determined, the set of houses to be sampled was chosen from the selected test area using random digit tables.

Test Area Sampling

The sampling began after the statistically significant sample size was determined. During a 1-week period, two samples of refuse were gathered from selected houses in the test area (Monday and Thursday are the usual days of garbage collection in Normandy Heights).

Two CERL employees manually collected the garbage from the selected housing units, placing the garbage from each housing site into plastic bags labeled for site identification purposes. The garbage was then transported via a flatbed truck to the recycling center for volume, weight, and composition analysis. Volume was measured by filling an empty

[23] G. Cochran, *Sampling Techniques*, 2nd ed. (John Wiley and Sons, Inc., 1966), p 25.

Table 5

Evaluation of Family Housing Groups

Housing Groupings	Category 1 Waste Characteristics		Category 2 Compliance With Source Segregation		Category 3 Study Costs
			Evaluation Factors		
	Economic Level	Age Group	Participation	Effectiveness	Same and Meet Concise Operational Constraints
Normandy Heights only	+	+	+	+	E
Bastogne Gables only	–	–	–	–	E
Bataan only	0	0	–	–	E
Normandy Heights and Bastogne Gables	0	0	0	0	D
Normandy Heights and Bataan	+	+	0	0	D
Bastogne Gables and Bataan	–	–	–	–	D
Two random areas	0	–	–	–	D
Three random areas	0	+	–	–	D

Legend:

+ Considered to have a positive bias on high-value waste or effective source separation.
0 Considered to have little or no bias on high-value waste or effective source separation.
– Considered to have a negative bias on high-value waste or effective source separation.
E Indicates relatively easy to keep sample within study budget constraints.
D Indicates relatively difficult to keep sample within study budget constraints.

55-gal (203.5-ℓ) metal drum with the refuse from each housing site. The refuse from each site was weighed and then manually sorted into the following categories:

1. Amber and green glass
2. Flint glass
3. Ferrous and bi-metals
4. Aluminum
5. Newsprint
6. Yard waste.

Each category was weighed separately for each household, and the results recorded.

The characterization data from the sample set of houses were then used to determine the average weight, volume, and composition of refuse from a typical family housing unit.

Current Refuse Disposal Program Evaluation

Family housing refuse collection at Fort Bragg is contracted to Haul-All of America of Daytona Beach, FL. The contractor furnishes all labor, equipment, and supervision necessary to collect and transport family housing refuse to the landfill. Collections are made twice weekly (Monday and Thursday). The contract stipulates that refuse must be collected on weekdays after 0600 hours or sunrise (whichever is later), and before 1700 hours or sunset (whichever is earlier). Specific collection routes and schedules, within the limits of the contract, are decided by the contractor. Each collection team consists of two helpers and a truck driver.

The following elements must be considered to effectively evaluate the current refuse disposal program.

1. Site Storage. The average Fort Bragg household uses two 32-gal (118.4-ℓ) metal trash cans. The cost of these cans is $22.75/can* which will be depreciated over a 5-year period.**

*1976 GSA Supply Catalog price for 32-gal (118.4-ℓ) metal trash can with lid.

**Standard IRS economic life for small equipment.

2. Collection and Transport. At Fort Bragg, collection and transportation costs from point of collection to point of disposal are $0.68 per household per week for two collections per week.* Insufficient data were available to accurately determine the separate costs of collection and transportation.

3. Landfill. The recently opened sanitary landfill site was selected by the Army Environmental Hygiene Agency. The landfill is properly constructed with an adequate confining layer of red clay, adequate cover material, substantial space, and a sloped open-end trench for runoff elimination. The landfill is located close enough to the cantonment for economical transport of solid wastes, yet far enough to avoid nuisance problems. The site is surrounded by wire trash fencing. Equipment on-site consists of one steel, wheeled trash compactor with trash rake, one self-propelled earth mover, one dozer-pulled earth mover, one crane with dragline, and one bulldozer and grader.

The mode of operation for the landfill is the trench method—the hole is cut to a red clay confining layer and then filled with refuse.

The landfill is open for waste disposal to all post personnel and any contractors picking up post trash. The refuse volume estimated by drivers is 60,000 to 70,000 cu yd/month (456 000 to 532 000 m³/month) (uncompacted) and the refuse weight is 135 tons/day (121.5 t/day) for both Fort Bragg and Pope AFB.

*Contract No. DAKF 40-75-B-0041.

Landfill disposal costs, including land, equipment, labor, and depreciation, were estimated to be $3/ton of refuse.[24]

4 STUDY RESULTS

Normandy Heights Area Refuse Characterization

To determine the quantity of recyclable materials generated by Normandy Heights area families, CERL researchers investigated the average daily refuse weight, volume, and composition for the area housing units. Normandy Heights has 163 dwelling units housing 742 people.

Using the statistical technique for sample size determination described in Chapter 3, error intervals were calculated as a function of sample size using Eq 1:

$$\triangle_{\bar{x}} = \sqrt{(\sigma_x^2/n)\left(\frac{N-n}{N}\right)} \cdot T_{90,n-1} \quad \text{[Eq 1]}$$

Literature values listed in Table 6 were used to calculate the average pounds of refuse production per housing unit per day, $\bar{x}$, and the sample standard deviation, σ_x. Table 7 gives the results of error interval calculations as a function of sample size.

[24]Personal communication of MAJ MacMullen, AFZA-FE-US, Fort Bragg, with Robert E. Freeman, SRI (4 December 1975).

Table 6

Quantity of Recyclable Material* in Residential Refuse

		Amount of Recyclables Estimated From Survey Data** (Pounds Per Day Per Housing Unit)			
	SCS #	National Data§	Quad City‖	Overall Average, $\bar{x}$	Standard Deviation, σ_x
Normandy Heights	3.55	5.83	6.42	5.27	1.52

*Glass, ferrous scrap, aluminum, newsprint, cardboard, and mixed paper.

**Entries are based on emission factors from references listed below. Weighted for 4.55 people/housing unit.

SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies* (USEPA, 1974).

§"1968 National Survey of Community Solid Waste Practices," *Municipal Refuse Disposal* (American Public Works Association, 1970).

‖*Quad City Solid Wastes Interim Report*, HEW Demonstration Grant No. 1-7-00026 (U.S. Department of Health, Education, and Welfare, 1968).

Table 7

Error Limits as a Function of Sample Size

Sample Size, n*	90% Confidence Variations** (± % of the mean x̄)
10	16.2
15	12.5
20	10.4
25	9.1
30	8.1
35	5.7

*Minimum sample sizes for various 90 percent confidence limits on the average estimate, x̄.

**Entries are the ± limits on the sample average to be 90 percent confident, including the community average, x̄.

It was decided that 10 percent was the maximum acceptable error in the estimated average. Thus, to be 90 percent confident that the estimated refuse values are within ± 10 percent of the sample value ($\bar{x}$), at least 20 houses should be sampled during a 1-week period.

A random digit table was used to eliminate any possible bias in the selection of housing units to be sampled. Table 8 gives the addresses of the 20 test houses selected.

Table 8

Location of the Sample Houses

Selection No.	Normandy Heights Housing Area Address
1	4 Capron Street
2	24 Capron Street
3	7 Pelham Street
4	10 Dupont Plaza
5	9 Dupont Plaza
6	26 Donelson Street
7	11 Donelson Street
8	1 Donelson Street
9	13 Adams Street
10	18 Adams Street
11	20 Adams Street
12	1 Hunt Street
13	10 Alexander Street
14	17 Dyer Street
15	2 Adams Street
16	3 Adams Street
17	5 Armistead Street
18	1 Hoyle Plaza
19	3 Hoyle Plaza
20	13 Hunt Street

The refuse from these 20 housing units was collected for the week of 16 February 1976, and analyzed for quantity and recyclable composition using the technique described in Chapter 2. Tables 9 and 10 give the results of the sampling. Results for housing units 14 and 20 were eliminated from calculations for Table 10 due to the atypical occurrence of packaging material from household moving activities and vacant housing units, respectively.

Table 11 compares national recyclables generation rates to the Normandy Heights area rates. Newsprint was the only material category which was not generated at a rate comparable to the national average for an upper middle income housing area. At best, the rate was 50 percent of the published average, possibly due to the lack of a major daily newspaper in the area.

Current Refuse Disposal Costs

The costs of storing, collecting, transporting, and disposing of the Normandy Heights area refuse were determined using the considerations described in Chapter 2:

Site storage costs

$$= \frac{163 \text{ units} \times 3 \text{ cans/unit} \times \$22.75/\text{can}^*}{5 \text{ years}^{**} \times 52 \text{ weeks/year}}$$

$$= \$42.79/\text{week}$$

Collection and transportation costs

$$= 163 \text{ units} \times \$0.68/\text{unit/week}\ \#$$

$$= \$110.84/\text{week}$$

Disposal costs

$$= \$3.00/\text{ton}^{25} \times \text{ton}/2000 \text{ lb}$$

$$\times 55.29\S \text{ lb/unit/week} \times 163 \text{ units}$$

$$= \$13.52/\text{week}$$

Total disposal cost = $167.15/week.

[25]Personal Communication of MAJ MacMullen, AFZA-FE-US, Fort Bragg, with Robert Freeman, SRI (4 December 1975).

*1976 GSA Supply Catalog price for 32-gal (118.4-ℓ) metal trash can with lid.

**IRS depreciation period for small equipment.

1976 family housing refuse collection contract with Haul-All of America.

§ From Table 10.

Table 9

Normandy Heights Recyclables Generation
(in pounds per week, 7-day week)

(metric conversion factors: 1 lb = 453.6 g; 1 gal = 3.785 ℓ)

Collection Number	Flint Glass	Amber and Green Glass	Cardboard	Newsprint	Bi-Metal	Aluminum	Total Recyclables	Miscellaneous Refuse	Total Weight	Total Volume (in gallons)	Collection Number	Notes
1*	2.00	4.00	11.00	3.50	0.75	0.25	21.50	44.50	66.0	123.00	1*	
2*	0.25	2.00	4.50	2.00	6.00	0.00	14.75	63.25	78.0	128.00	2*	
3*	2.00	11.00	0.00	3.50	1.25	0.00	17.75	32.25	50.0	45.83	3*	
4*	2.00	0.00	1.00	14.50	1.25	0.25	19.00	15.00	34.0	45.83	4*	
5*	1.00	1.00	0.00	15.25	0.75	0.50	18.50	40.50	59.0	73.33	5*	
6*	4.00	2.50	0.50	19.50	1.50	0.00	28.00	49.00	77.0	114.50	6*	
7*	2.00	0.50	0.00	0.25	1.00	0.25	4.00	8.00	12.0	18.33	7*	
8*	3.25	2.00	0.00	5.00	1.75	0.00	12.00	18.00	30.0	32.08	8*	
9*	1.00	0.00	0.50	4.00	2.00	0.00	7.50	34.00	41.5	55.00	9*	
10*	0.75	0.00	1.00	1.75	2.50	0.25	6.25	53.75	60.0	96.25	10*	
11*	1.00	0.00	3.00	0.50	1.50	0.00	6.00	19.00	25.0	55.00	11*	
12*	28.00	7.00	2.00	8.50	4.00	0.00	49.50	82.50	132.0	110.00	12*	
13*	1.25	1.50	0.25	4.25	1.25	0.75	9.25	32.75	42.0	82.50	13*	
14*					13.00	2.00	203.00	466.00	669.0	586.67	14*	1
15*	8.00	5.50	1.00	4.50	1.00	0.00	20.00	6.00	26.0	36.67	15*	2
16*	0.25	0.00	7.00	0.50	1.25	0.00	9.00	36.50	45.5	89.93	16*	3
17*	1.00	0.25	0.00	0.50	3.75	0.25	5.75	61.25	67.0	110.00	17*	
18*	25.00	17.00	0.25	0.50	3.00	2.00	47.75	67.25	115.0	128.33	18*	
19*	2.50	0.50	2.50	9.50	1.50	0.25	16.75	18.25	35.0	45.83	19*	
20*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	20*	4

Notes: (1) Families moving out of and into house
(2) 241 lb yard wastes
(3) 46 lb yard wastes
(4) House vacant during survey.

Table 10

Statistical Analysis of Sampled Refuse
(lbs/unit/week)

(metric conversion factor: 1 lb = 453.6 g)

Material	Average Value, x	Standard Deviation, σ,	90% Confidence Interval*	% of the Total Weight
Flint Glass	4.74	8.13	(1.41-8.07)	8.57
Amber/Green Glass	3.04	4.58	(1.16-4.92)	5.50
Cardboard	1.92	2.94	(0.72-3.12)	3.47
Newsprint	5.44	5.76	(3.08-7.80)	9.84
Ferrous/Bi-metal	2.00	1.38	(1.43-2.57)	3.62
Aluminum	0.26	0.48	(0.06-0.46)	0.47
Total Recyclables	17.40	13.13	(12.02-22.78)	31.47
Miscellaneous	37.88	21.85	(28.93-46.83)	68.53
Total Weight**	55.29	31.03	(42.58-68.00)	
Total Volume #	77.24	36.37	(62.34-92.14)	

*Interval = $\bar{x} \pm T_{90,n-1} (\alpha x/\sqrt{n})$

**Excluding yard wastes.

No moisture content was recorded.

Table 11

Recyclables Generation Rate Comparisons

(metric conversion factor: 1 lb = 453.6 g)

Material	Literature Averages*		Normandy Heights Averages #		Comparison§
	% Total	Lb/Unit/Wk**	% Total	Lb/Unit/Wk	
Ferrous/Bi-metal	4.4	2.28	3.6	2.00	Yes
Glass	11.7	6.02	14.1	7.78	Yes
Aluminum	0.8	0.40	0.5	0.26	Yes
Newsprint	32.3	16.33	9.8	5.44	No

*Adjusted SCS data to 4.55 persons/household from 3.4 persons/household. From SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies* (USEPA, 1974).

**Calculated by taking % total × 57.94, lb/unit/wk (From G. W. Schanche, L. A. Greep, J. R. Cannon, and B. A. Donahue, *Pollution Estimation Factors*. Technical Report N-12/ADA033753 [CERL, November 1976]).

Data from Table 10.

§"Yes" indicates the national average falls within the 90 percent confidence interval of the Normandy Heights average.

Recycling Program Costs

The costs for running the recycling program and separate refuse collection and disposal were determined using the techniques described in Chapter 2:

Refuse site storage costs

$$= \frac{3 \text{ cans/unit} \times 163 \text{ units} \times \$22.75/\text{can}}{5 \text{ years} \times 52 \text{ weeks/year}}$$

$$= \$42.79/\text{week}$$

Refuse collection and transportation costs

$$= 163 \text{ units} \times \$0.68/\text{unit/week} = \$110.84$$

Refuse disposal costs

$$= \$3.00/\text{ton} \times \text{ton}/2000 \text{ lb}$$

$$\times 24.78 \text{ lb*/unit/week} \times 163 \text{ units}$$

$$= \$5.98/\text{week}$$

*See Table 12.

Table 12

Quantities of Refuse Disposed—Normandy Heights*
(May 3, 1976—July 29, 1976)
(metric conversion factor: 1 lb = 453.6 g)

Week	Total Area (lb/week)	Individual Unit** (lb/unit/wk)
May 3	8500	52.15
May 10	5575	34.20
May 17	12010	73.68
May 24	7160	43.93
May 31	4700	28.83
June 7	800	4.91
June 14	1160	7.12
June 21	580	3.56
June 28	3320	20.37
July 5	2225	13.65
July 12	2130	13.07
July 19	1650	10.12
July 26	2050	12.58
Average	3989	24.47
Standard Deviation	3462	21.24
90 Percent Interval	(2277-5701)	(13.97-34.97)

*Data gathered by taking the change in refuse collection truck weight after each collection and summing the net refuse weight totals for each week.

**Individual unit = total area/163 units.

Recyclable material preparation costs

$$= \frac{\$0.02^{*}/\text{unit/month} \times 3 \text{ months} \times 149 \text{ units}^{**}}{13 \text{ weeks}}$$

$$= \$0.69/\text{week}$$

Recyclable material storage costs

$$= \frac{2 \text{ cans/unit} \times \$22.75/\text{can} \times 163 \text{ units}}{5 \text{ years} \times 52 \text{ weeks/year}}$$

$$= \$28.52/\text{week}$$

Recyclable material separate collection and transportation costs

$$= \$592.40^{\#} / 13 \text{ weeks} = \$45.57/\text{week}$$

Recyclable material processing and storage costs

$$= \frac{\$10/\text{ton}^{26} \times 8.34 \text{ tons}}{13 \text{ weeks}} = \$6.42/\text{week}$$

*Costs for using water, gas, and electricity to prepare and store recyclables. From SCS Engineers, Inc., *Analysis of Source Separation of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974).

**See Table 15 for average number of participating units per collection period.

See Table 13.

[26]S. J. Levy and H. G. Rigo, *Resource Recovery Plant Implementation Guide for Municipal Officials: Technologies*, SW-157.2 (USEPA, 1976).

Table 13

Recycled Materials Separate Collection and Transportation

	Hours	Hourly Rate	Total
Truck Use	34	7.02*	$238.68
Labor			
Driver	34	4.19**	$142.46
Laborers	63.25	3.34**	$211.26
Total			$592.40

**Decision-Makers' Guide in Solid Waste Management*, SW-500 (USEPA, 1976).

**Hourly wage-rate, including benefits given in DOD contract DAKF-40-75-13-0041.

Public relations costs

$$= \frac{\$0.33/\text{unit}^{*} \times 163 \text{ units}}{13 \text{ weeks}} = \$4.14/\text{week}$$

Transportation costs ferrous/bi-metal**

$$= \frac{\$12/\text{ton}^{27} \times 1.29 \text{ tons}^{\#}}{13 \text{ weeks}} = \$1.19/\text{week}$$

Revenue from sale of recyclables:

$$\text{Newsprint} = \frac{4741 \text{ lb}^{\S} \times \$0.01/\text{lb}}{13 \text{ weeks}} = \$3.65/\text{week}$$

$$\text{Glass} = \frac{8903 \text{ lb}^{\S} \times \$0.01/\text{lb}}{13 \text{ weeks}} = \$6.85/\text{week}$$

$$\text{Ferrous/bi-metal} = \frac{2579 \text{ lb}^{\S} \times \$0.005/\text{lb}}{13 \text{ weeks}}$$

$$= \$0.99/\text{week}$$

$$\text{Aluminum} = \frac{451 \text{ lb}^{\S} \times \$0.17/\text{lb}}{13 \text{ weeks}} = \$5.90/\text{week}$$

Total revenue = $17.39/week

Total recycling program cost = $228.75/week.

*SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974). Used $0.33/unit instead of $0.10/unit because of multiple public relations-related mailings.

**Glass, aluminum, and newsprint prices are all F.O.B. Fort Bragg; thus, there are no transportation costs.

[27]D. B. Sussman, *Resource Recovery Plant Implementation Guides for Municipal Officials: Accounting*, SW 157.6 (USEPA, 1976).

See Table 14.

§ See Table 14.

Table 14

Quantities of Recycled Materials

Material	Period I (5/1/76-6/4/76)	Period II (6/5/76-7/6/76)	Period III (7/7/76-8/3/76)	TOTAL (5/1/76-8/3/76)
Newsprint	2306	1625	810	4741
Glass	3408	3655	1840	8903
Ferrous/Bi-Metal	1360	1014	205	2579
Aluminum	145	211	95	451

Table 15

Household Participation in Recycling Program

Material	Period I (Participants)	Period I (% Total)	Period II (Participants)	Period II (% Total)	Period III (Participants)	Period III (% Total)	Average Participation (% Total)
Newsprint	68	41.7	46	28.2	60	36.8	35.6
Glass	134	82.2	139	85.3	143	87.7	85.1
Ferrous/Bi-Metal	131	80.4	141	86.5	137	84.0	83.6
Aluminum	61	37.4	29	17.0	42	25.8	27.0
Overall*	140	85.9	149	91.4	158	96.9	91.2

*Households which participated in at least one of the four recycling categories.

Table 15 shows the household participation in the recycling efforts during the study period. Glass and ferrous/bi-metals were the most actively recycled materials, with approximately 84 percent of the families participating. Overall participation increased steadily to a high of approximately 97 percent during the last period.

Table 16 depicts quantities of recyclables recovered from each participating household. As shown in Table 15, an average of 31 percent of the households that participated in recycling of newsprint and aluminum did so at a rate exceeding the amount of recyclables in the typical Normandy Heights area refuse. The high recovery rate for aluminum in Period II is most likely due to the 4th of July holiday period. Otherwise, household recycling of aluminum and newsprint is greater than normal, with virtually 100 percent recycled. Because of the large number of households participating (Table 15) and the closeness of the Normandy Heights and the national (Table 11) material generation rates, glass and ferrous/bi-metals seem to be the best estimators of what degree of material recovery can be expected.

5 DISCUSSION OF RESULTS

Program Evaluation

The recycling program was evaluated for both participant satisfaction and efficiency of design. User response was obtained by mailing out a short questionnaire (Appendix B). Of the 163 households in the Normandy Heights area, 54 filled out the questionnaire and returned it to CERL. The results were:

1. Sixty-six percent of the respondents felt that the program was successful, 28 percent had no opinion or were uncertain, and only 6 percent felt it was a failure.

2. Ninety-eight percent of the respondents felt that source separation recycling was a good way to conserve natural resources.

3. Eighty-seven percent of the respondents felt that use of the recycling revenues on post would enhance participation.

4. Fifty-two percent of the respondents had no complaints about the program, 44 percent had problems of some sort, and 4 percent had no opinion.

The most common participant complaints were:

1. Lack of space for kitchen storage of recyclables. Temporary storage of source-separated recyclables at the point of generation was a problem for many participants. Since the program only provided two 32-gal (1184-*l*) metal trash cans for interim exterior storage of recyclables, there was a need for some form of smaller storage container which could be conveniently placed in the kitchen. The problem

Table 16

Recyclable Material Recovery Rates
(pounds/participating unit/week)

Material	Period I*		Period II*		Period III*		Average # Participation	
	(Rate)	(% Total)**	(Rate)	(% Total)**	(Rate)	(% Total)**	(Rate)	(% Total)#
Newsprint	6.78	124.6	8.83	162.3	3.38	62.1	6.29	115.6
Glass	5.09	65.4	6.57	84.4	3.22	41.4	4.94	63.5
Ferrous/Bi-Metal	2.08	104.0	1.80	90.0	0.37	18.5	1.46	73.0
Aluminum	0.48	184.6	1.82	700.0	0.56	215.4	0.79	303.8

*Period I—5 weeks; Periods II and III—4 weeks.

**From Table 10: newsprint, 5.44 lb/unit/week; glass, 7.78 lb/unit/week; ferrous/bi-metal, 2.00 lb/unit/week; aluminum, 0.26 lb/unit/week.

Total recyclable material/average category participants/13 weeks.

could be remedied by providing several 7- to 10-gal (29.5- to 37-ℓ) rectangular or square containers having removable front-access lids for glass and metal storage, or glass, ferrous/bi-metals, and aluminum storage. Newspapers could be stored temporarily in a rectangular tray having dimensions equivalent to a newspaper folded in half, which could be placed on top of the 7- to 10-gal (25.9- to 37-ℓ) rectangular, front-access containers. These interior containers would be emptied periodically into the exterior storage containers.

2. Frequency of recyclable collections was inadequate. Several participants (20 percent of the survey respondents) complained that one collection per month was insufficient to keep the ferrous/bi-metal and/or glass containers from overflowing; however, more frequent collections would greatly increase the program costs, and mitigate a problem only affecting a small portion of the program participants. It would be more cost-effective to supply extra or larger storage containers for participants having overflow problems. A fireproof exterior storage container for newspapers would decrease the fire hazard posed by a 1-month accumulation of newspapers.

3. Recyclable collection schedule was not followed. Twenty percent of the survey respondents complained that pickups were either not made or not made at the scheduled time. This problem can be remedied by having full-time experienced collection personnel who are supervised closely.

4. Storage containers needed for aluminum and newspaper. Storage containers were supplied for glass and ferrous/bi-metal materials, but not for aluminum and newspaper. Participants were asked to bundle their newspapers and bag their aluminum cans. This portion of the program was not very successful, as can be seen in the decreased participation figures (Table 15) for aluminum and newspaper. To remedy this situation, storage containers for both aluminum cans and newspapers should be provided. If magnetic separation is used at the recycling center, the aluminum can be stored with the ferrous/bi-metal scrap, and only one additional container would be provided for the newspapers.

5. Too many trash cans. The addition of recycle storage cans created space problems on pads designed to hold only three trash cans. Source separation of waste requires separate storage containers for each segregated material. Recycling can reduce the number of refuse containers from three to two per unit, but it will also require a minimum of three extra containers (metals, glass, and newspaper). The best solution would probably be to provide a two-level rack which could hold up to six containers.

6. Newspaper should not be recycled. Several respondents complained that newspaper should not be recycled because it is inconvenient, poses a fire hazard, and lacks a stable market. Supplying households with fireproof exterior and interior storage containers designed specifically for newspapers would diminish the fire hazard and improve user convenience. The market problem could be ameliorated by providing adequate space at the recycling center for safe storage. When the market provides an adequate selling price, the stored newspapers could be shipped to the appropriate market and sold. This minimum selling price will be a function of market variability, storage costs, and handling/transportation costs.

7. Soldiers should not collect recyclables. Military personnel assigned to the recycling center assisted in the three monthly collections of the stored recyclables. In a full-scale recycling program, full-time, experienced civilian personnel would collect and process the recyclables.

Strong and Weak Points of the Program

Strong points of the Normandy Heights recycling program were:

1. High degree of cooperation. More than 90 percent (Table 15) of the Normandy Heights area residents participated in the recycling program. This compares favorably to the 75 percent participation rate reported by EPA[28] for upper income residential areas. Participants recycled the four different materials at recovery rates exceeding 75 percent (Table 16).

2. Study area was isolated. The Normandy Heights area was isolated from other housing areas at Fort Bragg, which decreased scavenging and dumping problems from outside sources.

3. Minimum disturbance of current refuse collection routine. As shown by participant comments, design and operation of the recycling study did not disrupt the normal collection of household refuse, but rather greatly decreased the amount of refuse that the contractor had to collect each week (Table 12).

4. Minimum quality control problems. During the study period, only 3 percent of the households used the storage containers as a trash can. The reminder sticker (Appendix B) helped to maintain the quality of recyclables by reminding participants to sort their refuse. Storage containers were removed at only two percent of the households during the first month of the study period because of a lack of cooperation.

Several problems in program design and operation became apparent during the study period. Some are the results of inefficient operation and could be corrected; others are the result of the study constraints listed in Chapter 1. The weak points of the program were:

1. Test area and study period were favorable to recycling. The selection of the Normandy Heights area and the summer study period may have biased the study in favor of recycling. Therefore, study conclusions cannot be directly applied to a total installation. The test area bias could have been eliminated by including Bastogne Gables in the recycling program. The climatological and seasonal biases could have been eliminated by conducting the program for longer than 3 months. Both of these options were identified during the program design phase but were not used because of funding limitations.

2. Storage containers were too expensive. Metal 32-gal (118.4-ℓ) storage containers for recyclables were selected to be compatible with the existing refuse containers. Depreciation on five metal storage containers (three refuse, two recycle) for each household represented 31 percent of the total cost of running the recycling program. By changing to 32-gal (118.4-ℓ), heavy-duty plastic storage containers, the depreciation cost could be reduced by 67 percent.

3. Inefficiency in recyclable collections. The recycling center's collection crews worked 32.42 manhours and used two trucks each month to collect recyclables from the Normandy Heights area. The refuse collection contractor serviced the same area with one truck in 5.63 manhours. This problem is the result of using inexperienced collectors and drivers and could be greatly improved by using experienced collection crews.

4. Inefficient refuse collection. As a result of the recycling program, average refuse production dropped from 33.0 lb/household/week to 24.47 lb/household/week (Tables 12 and 14). A 25 percent drop in average refuse production indicates underutilization of the collection crews. It would be very cost-effective to reduce refuse collections from two, to one per week.

5. Low participation in newspaper and aluminum. Newspaper and aluminum participation was approximately 30 percent, while glass and ferrous/bi-metals participation was approximately 85 percent (Table 15). The basic difference between the two material groups is that storage containers were provided for glass and ferrous/bi-metals but not for aluminum and newspapers. The storage containers

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[28] SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974).

served two functions: (1) they provided a convenient place for storing accumulated materials, and (2) they reminded participants to recycle these materials. Participation in newspaper and aluminum recycling could be greatly increased by providing storage containers for aluminum and newspapers.

6. Decline in Period III material recovery rates. The material recovery rates of newspaper, glass, and ferrous/bi-metals declined greatly during Period III in comparison to the previous two periods (Table 15), possibly because the public relations campaign was terminated in June. In July, there was no formal public relations program except for five quality control stickers in the 163-unit housing area. It has been reported that an active, continuing public relations program is fundamental to obtaining and maintaining public participation in household recycling.[29]

Means of Increasing Efficiency of Recycling Program

The following paragraphs discuss the savings effected by modifying the recycling program to improve user convenience and reduce inefficiencies. These revisions are applicable only to the Normandy Heights area recycling program, and include decreasing the number of trash cans per housing unit, decreasing the number of weekly collections, providing containers for exterior storage of recyclables, and using a professional collection crew.

Refuse Site Storage

Changing from three 32-gal (118.4-ℓ) metal trash cans per unit to two 32-gal (118.4-ℓ) heavy-duty plastic cans per unit is possible because more of the refuse is being recycled and handled separately, i.e., newspapers are bundled, aluminum cans are bagged, etc.

$$\frac{2 \text{ cans/unit} \times 163 \text{ units} \times \$7.40^{*}/\text{can}}{5 \text{ years} \times 52 \text{ weeks}}$$

$$= \$9.28/\text{week}$$

Refuse Collection and Transportation

Changing from two collections per week to one collection per week because of a decrease in refuse production will cost:

$$\$0.34^{*} \text{ /unit/week} \times 163 \text{ units} = \$55.42,$$

which is half as much as it formerly cost.

Problems with refuse storage capacity should not occur, since cans were originally sized to contain one week's volume of refuse (Table 9) — 77.24 gal/week (285.78 ℓ/week)—and this has also been reduced greatly.

Refuse Disposal

Refuse disposal costs will remain virtually unchanged if collections are decreased by a modified recycling program. Increasing participation in newspaper and aluminum recycling to 75 percent[30] would mean a 2.26 lb. (.9 kg)/unit/week reduction in the average amount of refuse disposed.

$$\$3.00/\text{ton} \times \text{ton}/2000 \text{ lb} \times 22.21 \text{ lb/unit/week}$$

$$\times 163 \text{ units} = \$5.43/\text{week}.$$

($3.30/t × t/2005 lb × 9 kg/unit/week

× 163 units = $5.43/week.)

Recyclable Material Preparation

These costs should remain the same, $0.69/week, or decrease, depending on whether the 90 percent overall participation rate can be maintained.

Recyclable Material Storage

Providing additional containers for exterior storage of accumulated aluminum would cost $3/unit;** glass, ferrous/bi-metals, and newspaper would cost $7.40/unit.#

[29] SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974).

*1976 GSA Supply Catalog price for 32-gal (118.4-ℓ) heavy-duty plastic trash can with lid.

*Assuming one collection per week would cost one-half the rate for two collections per week.

[30] Rate for upper income residential area. From SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection STudies*, PB-239-775 (USEPA, 1974).

**1976 GSA Supply Catalog price for 10-gal (37-ℓ) heavy-duty plastic trash can with lid.

Using a 32-gal (118.4-ℓ) plastic heavy-duty trash can.

$$\frac{(3 \text{ cans/unit} \times \$7.40/\text{can} \times 163 \text{ units}) + (1 \text{ can/unit} \times \$3.00/\text{can} \times 163 \text{ units})}{52 \text{ weeks/year} \times 5 \text{ years}}$$

$$= \$15.80/\text{week}$$

Recyclable Material Separate Collection and Transportation

Assuming an experienced recyclables collection crew would take twice as long to collect recyclables from the Normandy Heights area as the current contractor, the following costs would be incurred.

$$\frac{(5.63 \text{ manhours/collection} \times 2 \times \$3.65/\text{manhour}^*) + (2 \text{ truck hours/collection} \times 2 \times \$7.02/\text{truck hour}^{**})}{4.33 \text{ weeks/collection}}$$

$$= \$15.95/\text{week}.$$

Recyclable Processing and Storage Costs

Increasing aluminum and newspaper participation to 75 percent would increase the total amount of material to be processed by 2.40 tons for the 13-week study period and would cost:

$$\frac{\$10/\text{ton} \times 10.74 \text{ tons}}{13 \text{ weeks}} = \$8.26/\text{week}.$$

Public Relations Costs

Adding one public relations mailing per month would increase the PR postage costs by $0.13 per mailing.

$$\frac{(\$0.33/\text{unit} \times 163 \text{ units}) + (\$0.13/\text{unit/mailing} \times 3 \text{ mailings} \times 163 \text{ units})}{13 \text{ weeks}}$$

$$= \$9.03/\text{week}.$$

*Wage rate for one driver and 1.86 collectors from Table 13.
**See Table 13.

Transportation Costs (Ferrous/Bi-metals)

This cost would remain virtually the same, $1.19/week, since ferrous bi-metals participation would not be greatly influenced by increased public relations programs.

Revenue From the Sale of Recyclables

Newspaper

The quantity of newspaper would be increased both by better public relations and by providing participants with storage containers. Increasing participation to 75 percent would increase the total amount of newspaper recovered during the study period by 4526 lb (2036 kg).

$$\frac{9267 \text{ lb} \times \$0.01/\text{lb}}{13 \text{ weeks}} = \$7.13/\text{week}$$

$$\left(\frac{4198 \text{ kg} \times \$.022/\text{kg}}{13 \text{ weeks}} = \$7.13/\text{week}\right)$$

Glass

Revenue from glass would remain the same—$6.85/week.

Ferrous/Bi-metals

Revenue from ferrous/bi-metals would remain the same—$0.99/week.

Aluminum

The quantity of aluminum would be increased both by better public relations and by providing participants with separate storage containers. Increasing participation to 75 percent would increase the total amount of aluminum by 264 lb (105 kg) over the 13-week study period.

$$\frac{715 \text{ lb} \times \$0.17/\text{lb}}{13 \text{ weeks}} = \$9.35/\text{week}$$

$$\left(\frac{324 \text{ kg} \times \$0.38/\text{kg}}{13 \text{ weeks}} = \$9.35/\text{week}\right)$$

The total revenue would be $24.32/week.

Total Modified Recycling Program Cost

The total modified recycling program cost would be $96.73/week. Program cost-effectiveness could be improved by collecting recyclables concurrently with other refuse, which would greatly reduce the man-hours devoted to collecting both refuse and recyclables. This system would probably store collected recyclables in a rack or small trailer. Each week the refuse collection crew would pick up a different recyclable material and deliver it to the recycling center. The program would cost $1.38/ton ($1.39/t) of material collected for equipment modification and $14.42/ton ($14.44/t) of material collected to cover the cost of handling and transportation.[31] In the test program run in Normandy Heights, recyclable collection costs would drop from $45.57/week to $10.14/week. In the modified recycling program, recyclable collection costs would drop from $15.95/week to $13.05/week.

Program cost effectiveness could also be improved by use of a magnetic separator in the recycling center, which would improve participant convenience and cooperation. The cost of buying, installing, operating, and maintaining a 1500 cu ft/hour (the smallest sold) suspended permanent magnetic separator with a 12-in. (.3-m) belt would be approximately $4.32/week.[32] This unit's capacity would be sufficient to handle metal from the entire Fort Bragg residential population. The add-on approach for recyclable collections and the use of a magnetic separator at the recycling center would be feasible for only a total base residential recycling program. Collection equipment and recycling center modification would not be cost-effective for a smaller operation.

Effects of Beverage Container Deposit Regulation (40 CFR, Part 244)[33]

The Beverage Container Deposit Regulation is expected to reduce the glass content of wastes by 33 percent, ferrous/bi-metal content by 15 percent, and aluminum content by 30 percent.[34] The only aspect of recycling which would be greatly affected would be the revenue generated from the sale of recyclables. In the modified recycling outlined in Chapter 4, this would mean an increase of .54 percent—$5.22/week—in total program costs. This is not very significant and still makes source separation recycling feasible.

Marketing

Marketing costs were not considered in the experiment. Guidance on marketing has recently been published in DOD Directive 4165.60, which states that marketing is a Defense Supply Agency-Property Disposal Officer (PDO) function and that the cost for this service is 20 percent of the market value of the material being sold. This information was not available during the design phase of the experiment, and all costs and conclusions are based on actual or close estimations of the cost without considering PDO costs.

6 CONCLUSIONS

1. The demonstration project to determine the cost of recycling waste material from family housing indicated that the cost of the project, as constructed at Fort Bragg, was prohibitive. Researchers do conclude, however, that recycling by source separation can be cost-effective. This statement has some limitations which require clarification. Source separation recycling as an add-on system to existing refuse collection will increase costs. In this study, the cost of ultimate refuse disposal and/or recycling increased from $167.15/week to $228.75/week—a 36.8 percent increase in cost—as a result of an add-on recycling program. It was discovered, however, that recycling reduced the amount of refuse to be landfilled by an average of 25 percent and could therefore reduce collections from twice to once per week. This factor, along with switching from metal to plastic cans, could help reduce ultimate refuse disposal costs from $167.15/week to $96.73/week—a 42.2 percent reduction. It can be stated that source separation recycling is cost-effective when the refuse collection and disposal is also modified to reduce resultant inefficiencies.

[31] Prices expressed in 1976 dollars instead of 1974 dollars. From SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies* USEPA, 1974).

[32] Cost figure is reported in 1976 dollars, assuming a 10-year operating life and 7.5 percent operating and maintenance costs (Eriez Magnetics, 1976). From N. L. Drokny, H. E. Hull, and R. F. Testin, *Recovery and Utilization of Municipal Solid Waste* (USEPA, 1971).

[33] *Code of Federal Regulations*, 40 CFR 244 (General Services Administration, 1976).

[34] *Decision Makers' Guide in Solid Waste Management*, SW-500 (USEPA, 1976).

2. Military family housing generates refuse comparable to that of the civilian sector. As a result of the test area refuse characterization, it was found that Normandy Heights generates refuse and recyclables at a rate comparable to the civilian sector. All recyclables except newspapers are generated at a rate similar to that of the civilian sector. Total refuse generated in Normandy Heights is 55.29 lb (22 kg)/unit/week, which is comparable to the 57.94 lb (23 kg)/unit/week rate estimated for military housing.[35]

3. Military personnel will participate in a source separation recycling program. More than 91 percent of the families in the Normandy Heights area participated in some way in the source separation recycling program. This is far greater than the 75.0 percent rate given by the EPA for upper level income groups.[36] More than 60 percent of the available recyclable materials were recovered from waste collected from participating households.

4. Recycling reduces the amount of refuse to be landfilled. Comparisons of quantities of refuse disposed and quantities of recycled materials for the Normandy Heights area show an average refuse weight reduction of 25 percent.

5. Experienced personnel should collect recyclables. Analysis of collection labor data showed that inexperienced recycling center personnel took almost six times longer than professionals to collect recyclables from Normandy Heights.

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[35] G. W. Schanche, L. A. Greep, J. R. Cannon, and B. A. Donahue, *Pollution Estimation Factors*, Technical Report N-12/ADA033753 (CERL, 1976).

[36] SCS Engineers, Inc., *Analysis of Source Separation Collection of Recyclable Solid Waste—Separate Collection Studies*, PB-239-775 (USEPA, 1974).

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APPENDIX A:

NORMANDY HEIGHTS EDUCATION AND PUBLIC RELATIONS

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
P.O. BOX 4005
CHAMPAIGN, ILLINOIS 61820

CERL-ENE

9 April 1976

Dear Normandy Heights Residents:

As part of the U. S. Army continuing effort in resource conservation, the Normandy Heights area, at Fort Bragg, is being asked to participate in a study to determine the cost and benefits of voluntary refuse recycling by families.

Refuse sampling began on the base in early 1976 to determine both the volume and composition of recyclable materials. On the basis of the sampling results, we are asking the families in the Normandy Heights area to participate in a two-month recycling program, beginning the first week in May.

During the program, recyclable materials (such as glass, paper and aluminum cans) will be picked up monthly and stored at the Fort Bragg recycle center for resale to local markets. It is anticipated that the profits from the sale of recyclables will be used at Fort Bragg.

A meeting will be held in your community in early May to provide additional information concerning the recycling program. Instructions and exact details will be forthcoming.

Your cooperation in this study is an essential ingredient to its success. We hope your response will be enthusiastic.

Sincerely,

Bernard A. Donahue

B. A. Donahue
Environmental Engineering Team

CERL-ENE 23 April 1976

Dear Normandy Heights Resident:

As you know, the Normandy Heights area of Ft. Bragg has been asked to participate in a study of solid waste recycling from family housing areas. It is estimated that over 50% of household solid waste can be recycled. Since solid wastes are becoming more costly and difficult to adequately dispose, recycling can both diminish the amount of material to be disposed as well as reduce the irreversible depletion of our natural resources. This study will help determine the feasibility of establishing full-scale recycling programs in Army family housing areas.

This letter supplies the details of how to participate in this study. Starting May 1 and continuing through August 3, we are asking you to save out all glass, bi-metal cans, aluminum cans, and newspaper from your normal refuse. These materials will be collected monthly by the recycling center. Enclosure #1 gives the details on what to save, how to prepare the materials, and when separate recyclable collections will occur. During the course of this study, we ask that you dispose of your non-recyclable refuse just as before. In addition, we ask that you not participate in any other recycling effort (e.g., paper drives, glass drives, or aluminum drives). Proceeds from this study will be reused on Ft. Bragg.

Studies conducted by the U.S. Environmental Protection Agency indicate that this type of recycling program requires a very small effort on the part of the householder. It is estimated that it will require you to spend about 15 minutes per week to prepare and store recyclables. Approximately 2 cents per week will be spent on preparation materials, and storage of recyclables will take up about 10 square feet of space.

We sincerely hope that you will take an active interest in this program and will give us the opportunity to make a positive contribution to improving our environment. A meeting will be held on Thursday, April 29, at 1030 hrs. in the Corps Conference Room, Headquarters building, to answer any questions, present additional information (16 minute film on recycling), and solicit your suggestions. We ask that you attend.

CERL-ENE 23 April 1976
Normandy Heights Residents

We anticipate that the results of this study will provide valuable input to the Army's recycling policy. The results will be tabulated and sent to each participant in the Normandy Heights area.

The point of contact for this project on Ft. Bragg is Bruce Anderson (phone: 396-8891). Any questions or problems which you have will be handled by Mr. Blanchard (phone: 396-2618).

Thank you for your kind attention and consideration.

Sincerely,

Bernard A. Donahue

Bernard A. Donahue

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
P. O. BOX 4005
CHAMPAIGN, ILLINOIS 61820

CERL-ENE

17 March 1977

Dear Normandy Heights Residents:

First of all, let me thank you for your participation in last summer's study of voluntary refuse recycling by Normandy Heights area families. Analysis of the three-month pilot program has been completed and the results are very promising.

For the three-month period, over 90 percent of Normandy Heights families participated in the program with 85 percent participating in glass and bi-metal can recycling and 30 percent of the families participating in aluminum and newspaper recycling. These recycling efforts reduced the average amount of refuse going into the landfill by approximately 56 percent and generated a total of 8.34 tons of recyclable material. This material had a market value of approximately $225. Proceeds from the sale of this material has remained on Ft. Bragg.

A full-scale voluntary refuse recycling program of this type could reduce the amount of refuse to be landfilled by up to 65 percent, and the residential refuse disposal costs could be reduced considerably. More importantly, perhaps, is that a successful recycling program would mean conservation of valuable natural resources and landfill space.

Beginning sometime in the fall of 1977, Ft. Bragg has agreed to participate with CERL in a metal beverage container and metal can recycling demonstration. This recycling program will be conducted post wide and will include family housing, clubs, etc. If you have any comments or suggestions on how you feel this demonstration project can best be accomplished, please address your ideas to:

U.S. Army Construction Engineering Research Laboratory
ATTN: Environmental Division/B. A. Donahue
P.O. Box 4005
Champaign, Illinois 61820

CERL-ENE 17 March 1977

Thank you again for your valuable contributions to this resource conservation research project.

Sincerely yours,

Bernard A. Donahue

BERNARD A. DONAHUE
Environmental Engineering Team

RECYCLING INFORMATION SHEET

	Newsprint	Glass	Bi-Metal Cans	Aluminum Cans
What	Dry newsprint print (no magazines, cardboard or books).	Any color of non-returnable glass.	Identified by side seam, bottom seam, magnetic (See Encl 2)	Identified by no side seam, rolled bottom, and non-magnetic (See Encl. 2)
How	Bundle and tie with string or twine	Place in garbage can marked GLASS (rinse and remove aluminum rings)	Rinse and place in garbage can labeled BI-METAL Flatten or nest to conserve space	Save in a shopping bag or other handy container. Flatten to conserve space.
When	Put bundles out near cans before 0900 hours on: 1 June 76 6 July 76 3 Aug 76 (In case of rain, place bundles out one week later.)	Place in marked garbage cans to be picked up on: 1 June 76 6 July 76 3 Aug 76	Place in marked garbage cans to be picked up on: 1 June 76 6 July 76 3 Aug 76	Put aluminum cans out before 0900 hrs. on: 1 June 76 6 July 76 3 Aug 76 (In case of rain, place out one week later with newspapers.)

Additional Notes:

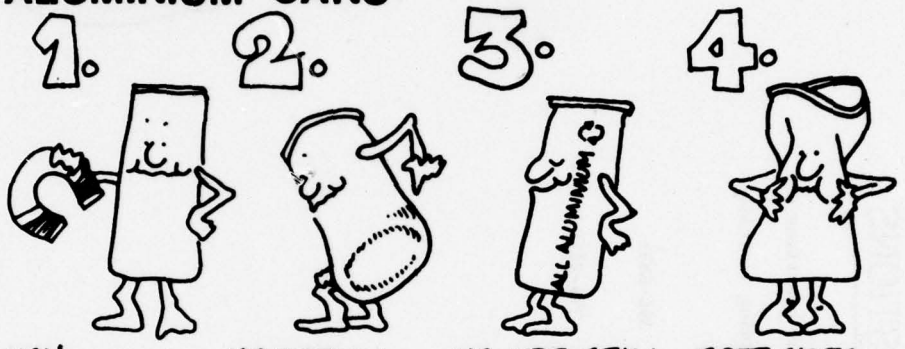
1. PLACE OTHER GARBAGE IN THE UNMARKED GARBAGE CANS SO THAT IT CAN BE COLLECTED AS USUAL.

2. PLEASE DON'T MIX RECYCLABLES OR CONTAMINATE RECYCLABLES WITH GARBAGE, AS THIS MAKES THE WHOLE BATCH UNUSABLE.

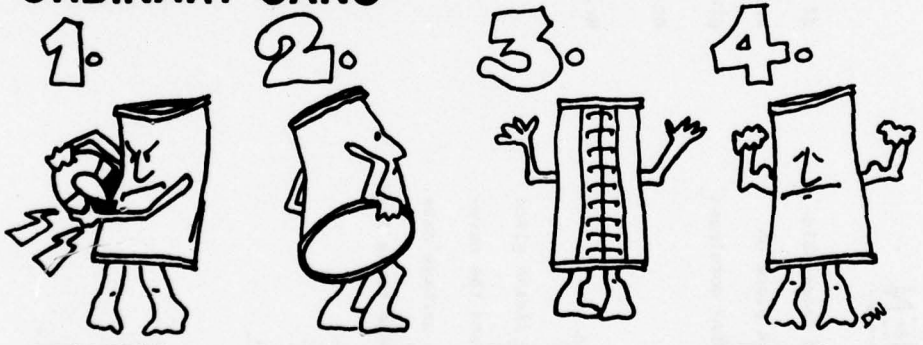
3. ABNORMAL ACCUMULATION OF RECYCLABLES THAT CANNOT BE CONVENIENTLY STORED WILL BE PICKED UP BY THE RECYCLING CENTER (PHONE: 396-5424).

HOW TO TELL RECYCLABLE ALUMINIUM CANS FROM ORDINARY BI-METAL CANS

ALUMINIUM CANS:



ORDINARY CANS:



environmental engineering team
us army·cerl·champaign il 61820

WHEN

Collection of your recyclable materials will take place on the following TUESDAY mornings:

01 June 1976

06 July 1976

03 August 1976

On collection day, please place the aluminum cans and the newsprint next to your garbage cans. In case of rain place these items out one week later.

QUESTIONS

If you have any questions or problems regarding recycling, please contact:

Mr. Anderson: 396-8891

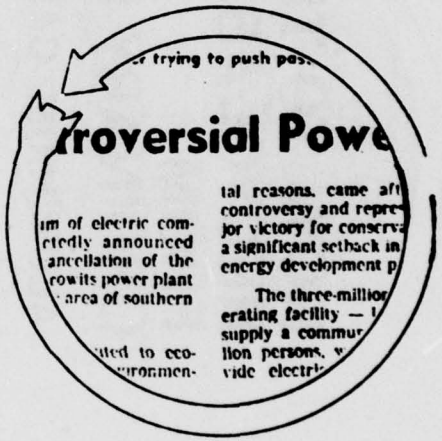
or

Mr. Blanchard: 396-2618

REMEMBER

TO

RECYCLE



WHY

In the United States alone the annual solid waste volume is four billion tons. Recycling can greatly reduce this volume going into sanitary landfill (dump). Additionally, recycling is a more environmentally acceptable way to dispose of one's trash. For every ton of paper recycled, one tree can be saved.

WHAT

Newspapers

- Newsprint only. Please, no magazines, cardboard, or other paper products.

Glass

- Glass of any color or size. This is not limited to just beverage containers but to all glass items.

Aluminum

- Both aluminum cans and aluminum foil.
- You can tell an aluminum can by using the enclosed "RECYCLING MAGNET" (a magnet will not stick to aluminum but will stick to the bi-metal).

Bi-Metal

- All bi-metal cans.

HOW

Newspapers

- Please bundle and stack your newspapers. Use twine or string to tie them.

Glass

- Rinse glass containers and remove their labels, then place them in the specially provided recycling can. Beverage containers that have metal rings on their necks must have the rings removed. This can easily be done with a screwdriver to pry them off.

Aluminum and Bi-Metal Cans

- Please flatten aluminum and bi-metal containers. Store the aluminum cans until collection day in a shopping bag or other handy container. Please rinse the bi-metal cans, then place them in the provided recycling can.

APPENDIX B:

DATA COLLECTION FORMS

INSTRUCTIONS FOR COMPLETING *RECYCLABLE COLLECTION FORM*

Complete one of these forms for each collection truck for each collection run (e.g., if 2 collection trucks are used and each makes 2 collection runs, then 4 forms should be completed).

1. Enter the day's date at the top of the form next to "DATE" (e.g., Tuesday, June 1 would be 6/1/76).

2. Enter the collection run number next to "RUN" and the total number of collection runs made for that day next to "RUNS" (e.g., if a form contains data for the first of four collection runs, it would be noted as "RUN *1* of *4* RUNS").

3. Record *TRUCK MILEAGE* information for each collection run by entering the starting mileage next to "START" and the stopping mileage next to "END". Starting mileage should be recorded before leaving the Recycle Center and stopping mileage should be recorded after returning to the Recycle Center.

4. Record the empty weight of collection truck and crew next to "EMPTY" and record the full weight of collection truck, crew and recyclables next to "FULL". Make sure that the same crew members are on the truck for both "EMPTY" and "FULL" weights.

5. Record the net weights of the collected recyclable materials next to the applicable categories. To determine net weights:

a. Remove recyclables from collection truck and segregate by material type (glass, bimetal cans, aluminum and newspapers).

b. Weigh an empty 55 gallon drum (for glass, bimetal cans and aluminum only) and note empty weight.

c. Fill the pre-weighed 55 gallon drum with a single material type and note full weight. (glass, bimetal and aluminum only.)

d. Determine the net weight of material contained in the 55 gallon drum by subtracting the empty weight (step b) from the full weight (step c) and note.

e. Repeat steps c & d as many times as is necessary to weigh the full amount of a single material type (glass, bimetal or aluminum). Sum the net weights (step d) for a single material type and record the number next to the appropriate "NET WEIGHT" (e.g. the sum of all the net weights of glass would be recorded next to "*NET WEIGHT-GLASS*").

f. To determine the "*NET WEIGHT-NEWSPAPERS*", place collected newspaper bundles directly on the scales, noting weights of various loads, until all collected newspaper has been weighed. Sum the weights of the loads and record the number next to "NET WEIGHT-NEWSPAPERS".

6. Record the number of collection crew members next to "CREW SIZE".

7. Note the weather conditions during the collection run by checking the appropriate boxes next to "WEATHER".

8. Once recyclable collection has been completed, gather all the completed forms together and give them to Bruce Anderson or send them directly to:

BERNARD A. DONAHUE
US ARMY CERL-ENE
PO BOX 4005
CHAMPAIGN, IL 61820

INSTRUCTIONS FOR COMPLETING *RECYCLING PROGRAM PARTICIPATION FORM*

Complete one of these forms for each recyclable collection.

1. Enter the date of the collection run at the top of the form (e.g., Tuesday, June 1, would be 6/1/76).

2. Residence addresses for the Normandy Heights area are listed in the order of their most efficient collection. Participation by each location should be noted by checking the appropriate boxes. (e.g., 42 Bassett Street puts out aluminum cans and newspapers, "Aluminum" and "Newspapers" boxes should be checked and "Bimetal" and "Glass" boxes should be left blank.)

3. In the event that any of the recyclable categories are contaminated by trash, the following actions should be taken:

   a. Dispose of the contaminated category as trash. DO NOT HAND SORT (e.g., trash in the "Glass" *recycle can).*

   b. Peel off one of the printed warning labels and place on the offending recyclable container in a conspicuous place (e.g., on top of the lid).

   c. Identify the offending residences by writing "TRASH" in the appropriate categories on the form. (e.g., 23 Hunt puts trash in the "BIMETAL" can, "TRASH" should be written in the "BIMETAL" box.)

4. Turn in completed form to Bruce Anderson or mail directly to:

BERNARD A. DONAHUE
US ARMY CERL - ENE
PO BOX 4005
CHAMPAIGN, IL 61820

RECYCLING PROGRAM

1. Was the program a success ☐ or failure ☐ ?

2. How could it have been improved? _____
   _____
   _____

3. Do you feel that recycling is a good way to conserve resources? YES ☐ NO ☐

4. Would you participate more fully in recycling if the money from the sale of recyclables were used for a good cause on the installation where it was collected? YES ☐ NO ☐

5. Have you had any problems with recycling as it has been set up for this experiment? YES ☐ NO ☐
   If yes, what were the problems and how could they have been corrected? _____
   _____
   _____
   _____

CERL-ENE

RECYCLABLE COLLECTION

DATE: _____ Run _____ of _____ Runs

TRUCK MILEAGE: start: _____

end: _____

TIME: start: _____

end: _____

WEIGHT: Empty (truck & crew): _____ lb

Full (truck, crew & recyclables): _____ lb

Net weight - Newspapers: _____ lb

Net weight - Glass: _____ lb

Net weight - Bi-metal cans: _____ lb

Net weight - Aluminum: _____ lb

CREW SIZE: _____

WEATHER: clear _____ hot _____

drizzle _____ warm _____

rain _____ cold _____

CERL-ENE Form # 1

Instructions for Completing the

Refuse Collection Record

Complete one of these cards for each refuse collection run made in the Normandy Heights family housing area. This would mean filling out three cards on days when three collection runs are made through the Normandy Heights area and one card on days when one collection run is made.

1. Enter the day's date at the top of the card next to "Date" (e.g., Monday May 10 would be 5/10/76).

2. Record the time refuse collection for that run begins in the Normandy Heights family housing area next to "Start Time".

3. Enter the time that refuse collection for that run in the Normandy Heights area ends next to "End Time".

4. Record the weight of the collection truck and crew before the refuse collection run begins in the Normandy Heights area next to "Weight In".

5. Record the weight of collection truck and crew after the collection run ends in the Normandy Heights area next to "Weight Out".

6. Record the number of collection team members (including driver) next to "Crew Size".

7. Indicate the weather conditions during the collection run by checking the appropriate boxes.

8. Turn in all completed collection cards to Mr. Blanchard, Refuse Collection Foreman, at the end of the day (usually Mondays and Thursdays).

REFUSE COLLECTION RECORD

DATE: _____

START TIME: _____

END TIME: _____

WEIGHT IN: _____
(truck & crew)

CREW SIZE: _____

WEATHER:

clear _____ hot _____

drizzle _____ warm _____

rain _____ cold _____

CERL-ENE Form #3

Instructions for Completing

Refuse Collection Summary

Record all the data contained on the completed Refuse Collection Record cards on the summary sheet. Use one column for each completed card.

1. Enter the date of the collection run at the top of the column.
2. Enter the starting and stopping times in the appropriate boxes.
3. Enter the starting and ending vehicle weights in the appropriate boxes.
4. Record the number of refuse collection team members in the "Crew Size" box.
5. Check the boxes which describe the weather conditions encountered during the collection run.
6. Send the completed Refuse Collection Record cards at the end of each week to:

Bernard A. Donahue
U.S. Army CERL-ENE
PO Box 4005
Champaign, IL 61820

REMINDER STICKER PLACED ON TRASH CANS

HOW CAN WE REUSE
YOUR REFUSE
IF YOU REFUSE
TO SORT IT ?

REFUSE COLLECTION SUMMARY

	Date			
TIME				
start				
end				
WEIGHT				
in				
out				
CREW SIZE				
WEATHER				
clear				
drizzle				
rain				
hot				
warm				
cold				

CERL-ENE Form #4

Date:

RECYCLING PROGRAM PARTICIPATION FORM

1. Check applicable boxes to indicate participation.

2. If recyclables are contaminated by trash, DO NOT SORT - dispose of it and note it on the form by writing "TRASH" in the applicable boxes.

No.	Location	Participation			
		Alumi-num	Bi-metal	Glass	News-print
9	Bassett Street				
11	Bassett Street				
13	Bassett Street				
15	Bassett Street				
14	Bassett Street				
16	Bassett Street				
17	Bassett Street				
19	Bassett Street				
18	Bassett Street				
20	Bassett Street				
21	Bassett Street				
23	Bassett Street				
22	Bassett Street				
24	Bassett Street				
26	Bassett Street				
28	Bassett Street				
30	Bassett Street				
32	Bassett Street				
34	Bassett Street				
36	Bassett Street				
38	Bassett Street				
40	Bassett Street				
42	Bassett Street				
44	Bassett Street				

CERL-ENE Form #5

No.	Location	Alumi-num	Bi-metal	Glass	News-print
46	Bassett Street				
48	Bassett Street				
50	Bassett Street				
52	Bassett Street				
53	Bassett Street				
51	Bassett Street				
43	Bassett Street				
41	Bassett Street				
39	Bassett Street				
37	Bassett Street				
41	Hunt Street				
39	Hunt Street				
42	Hunt Street				
40	Hunt Street				
32	Hunt Street				
27	Hunt Street				
30	Hunt Street				
25	Hunt Street				
28	Hunt Street				
26	Hunt Street				
23	Hunt Street				
24	Hunt Street				
21	Hunt Street				
22	Hunt Street				
20	Hunt Street				
19	Hunt Street				
29	Donelson Street				
31	Donelson Street				
33	Donelson Street				
35	Donelson Street				
37	Donelson Street				
39	Donelson Street				
34	Capron Street				
32	Capron Street				

CERL-ENE Form #5

No.	Location	Alumi-num	Bi-metal	Glass	News-print
30	Capron Street				
28	Capron Street				
34	Donelson Street				
36	Donelson Street				
7	Dupont Plaza				
9	Dupont Plaza				
11	Dupont Plaza				
13	Dupont Plaza				
38	Donelson Street				
40	Donelson Street				
14	Dupont Plaza				
12	Dupont Plaza				
10	Dupont Plaza				
8	Dupont Plaza				
26	Capron Street				
1	Pelham Street				
3	Pelham Street				
5	Pelham Street				
7	Pelham Street				
24	Capron Street				
22	Capron Street				
20	Capron Street				
18	Capron Street				
10	Capron Street				
8	Capron Street				
6	Capron Street				
4	Capron Street				
2	Capron Street				
2	Sedgewick Street				
23	Dyer Street				
21	Dyer Street				
19	Dyer Street				
17	Dyer Street				
12	Alexander Street				

CERL-ENE Form #5

No.	Location	Alumi-num	Bi-metal	Glass	News-print
15	Dyer Street				
10	Alexander Street				
13	Dyer Street				
11	Dyer Street				
8	Alexander Street				
6	Alexander Street				
4	Alexander Street				
2	Alexander Street				
9	Dyer Street				
7	Dyer Street				
5	Dyer Street				
2	Adams Street				
1	Hunt Street				
1	Adams Street				
6	Adams Street				
3	Hunt Street				
5	Hunt Street				
8	Adams Street				
10	Adams Street				
7	Hunt Street				
12	Adams Street				
14	Adams Street				
9	Hunt Street				
16	Adams Street				
18	Adams Street				
11	Hunt Street				
13	Hunt Street				
6	Dupont Plaza				
4	Dupont Plaza				
20	Adams Street				
15	Adams Street				
17	Adams Street				
2	Dupont Street				
4	Totten Street				

CERL-ENE Form #5

No.	Location	Alumi-num	Bi-metal	Glass	News-print
2	Totten Street				
1	Totten Street				
3	Totten Street				
1	Dupont Plaza				
2	Couchman Street				
4	Couchman Street				
3	Couchman Street				
3	Dupont Plaza				
5	Dupont Plaza				
15	Hunt Street				
26	Donelson Street				
24	Donelson Street				
22	Donelson Street				
1	Couchman Street				
19	Donelson Street				
17	Donelson Street				
15	Donelson Street				
13	Donelson Street				
11	Donelson Street				
9	Donelson Street				
7	Donelson Street				
5	Donelson Street				
3	Donelson Street				
1	Hoyle Plaza				
3	Hoyle Plaza				
1	Donelson Street				
13	Adams Street				
9	Adams Street				
7	Adams Street				
5	Hoyle Plaza				
5	Adams Street				
7	Hoyle Plaza				
3	Adams Street				

CERL-ENE Form #5

No.	Location	Alumi-num	Bi-metal	Glass	News-print
7	Armistead				
5	Armistead				
3	Armistead				
1	Armistead				

Picatinny Arsenal
ATTN: SMUPA-VP3

US Army, Europe
ATTN: AEAEN

Director of Facilities Engineering
APO New York 09827

DARCOM STIT-EUR
APO New York 09710

West Point, NY 10996
ATTN: Dept of Mechanics
ATTN: Library

HQDA (SGRD-EDE)

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-FEB
ATTN: DAEN-FEP
ATTN: DAEN-FEU
ATTN: DAEN-FESA
ATTN: DAEN-FEZ-A
ATTN: DAEN-MCZ-S
ATTN: DAEN-RDL
ATTN: DAEN-ZCE
ATTN: DAEN-PMS (12)
for forwarding to
National Defense Headquarters
Director General of Construction
Ottawa, Ontario K1AOK2
Canada

Canadian Forces Liaison Officer (4)
U.S. Army Mobility Equipment
Research and Development Command
Ft Belvoir, VA 22060

Div of Bldg Research
National Research Council
Montreal Road
Ottawa, Ontario, K1AOR6

Airports and Const. Services Dir.
Technical Information Reference
Centre
KAOL, Transport Canada Building
Place de Ville, Ottawa, Ontario
Canada, K1AON8

British Liaison Officer (5)
U.S. Army Mobility Equipment
Research and Development Center
Ft Belvoir, VA 22060

Aberdeen Proving Ground, MD 21005
ATTN: AMXHE/J. D. Weisz

Ft Belvoir, VA 22060
ATTN: Learning Resources Center
ATTN: ATSE-TD-TL (2)
ATTN: Kingman Bldg, Library

US Army Foreign Science & Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office

Ft Monroe, VA 23651
ATTN: ATEN
ATTN: ATEN-FE-E
ATTN: ATEN-FE-U

Ft Lee, VA 23801
ATTN: DRXMC-D (2)

Ft McPherson, GA 30330
ATTN: AFEN-FED

USA-CRREL

USA-WES
ATTN: Library

5th US Army
ATTN: AFKB-LG-E
z
6th US Army
ATTN: AFKC-LG-E

US Army Engineer District
Pittsburgh
ATTN: Library
ATTN: Chief, Engr Div
Philadelphia
ATTN: Library
ATTN: Chief, NAPEN-E
Baltimore
ATTN: Library
Norfolk
ATTN: Library
ATTN: Chief, NAOEN-D
Huntington
ATTN: Library
ATTN: Chief, ORHED-H

US Army Engineer District
Wilmington
ATTN: Chief, SAWEN-PM
ATTN: Chief, SAWEN-E
Charleston
ATTN: Chief, Engr Div
Savannah
ATTN: Library
ATTN: Chief, SASAS-L
Jacksonville
ATTN: Library
ATTN: Env. Res. Br.
Mobile
ATTN: Library
ATTN: Chief, SAMEN-C
Nashville
ATTN: Library
Memphis
ATTN: Library
Vicksburg
ATTN: Chief, Engr Div
Louisville
ATTN: Library
ATTN: Chief, Engr Div
Detroit
ATTN: Library
St. Paul
ATTN: Chief, ED-H
Chicago
ATTN: Chief, NCCCO-R
ATTN: Chief, NCCED-H
ATTN: Chief, NCCPD-ER
St. Louis
ATTN: Library
ATTN: Chief, ED-B
ATTN: Chief, ED-D
Kansas City
ATTN: Library (2)
ATTN: Chief, Engr Div
Omaha
ATTN: Chief, Engr Div
New Orleans
ATTN: Library (2)
Little Rock
ATTN: Chief, Engr Div
Tulsa
ATTN: Chief, Engr Div
Fort Worth
ATTN: SWFED-D
ATTN: SWFED-MA/MR
Galveston
ATTN: Chief, SWGAS-L
ATTN: Chief, SWGCO-M
Albuquerque
ATTN: Library
Los Angeles
ATTN: Library
ATTN: Chief, SPLED-E
San Francisco
ATTN: Chief, Engr Div
Sacramento
ATTN: Chief, SPKED-D
Far East
ATTN: Chief, Engr Div
Japan
ATTN: Library
Portland
ATTN: Library
Seattle
ATTN: Chief, NPSEN-FM
ATTN: Chief, EN-DB-SE
ATTN: Chief, NPSEN-PL-WC
ATTN: Chief, NPSEN-PL-ER
Walla Walla
ATTN: Library
ATTN: Chief, Engr Div
Alaska
ATTN: Library
ATTN: NPADE-R
Europe
ATTN: Technical Library
New England
ATTN: Library (2)
ATTN: Chief, NEDED-D
North Atlantic
ATTN: Library
ATTN: Chief, NADEN-T
Middle East (Rear)
ATTN: MEDED-T
South Atlantic
ATTN: Chief, SADEN-TE
ATTN: Library
Huntsville
ATTN: Library (2)
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-ME
ATTN: Chief, HNDED-SR
Lower Mississippi Valley
ATTN: Library
ATTN: Chief, PD-R
Ohio River
ATTN: Library
ATTN: Chief, Engr Div
North Central
ATTN: Library
ATTN: Chief, Engr Planning Br

US Army Engineer Division
Missouri River
ATTN: Library (2)
ATTN: Chief, MRDED-T
Southwestern
ATTN: Library
ATTN: Chief, SWDED-TH
South Pacific
ATTN: Chief, SPDED-TG
ATTN: Laboratory
Pacific Ocean
ATTN: Chief, Engr Div
ATTN: Chief, PODED-MP
ATTN: Chief, PODED-P
North Pacific
ATTN: Chief, Engr

Facilities Engineer
Carlisle Barracks, PA 17013
Ft Campbell, KY 42223
Ft Hood, TX 76544
FORSCOM
Ft Devens, MA 01433
Ft George G. Meade, MD 20755
Ft McPherson, GA 30330
Ft Sam Houston, TX 78234
Ft Lewis, WA 98433
USAECOM
Ft Monmouth, NJ 07703
DSCPER
West Point, NY 10996
USATCFE
Ft Eustis, VA 23604
USAIC (3)
Ft Benning, GA 31905
USAAVNC (2)
Ft Rucker, AL 36361
CAC&FL
Ft Leavenworth, KS 66027
AMC
Dugway, UT 84022
USACC
Ft Huachuca, AZ 85613
TRADOC
Ft Dix, NJ 08640
Ft Belvoir, VA 22060
Ft Monroe, VA 23651
Ft Lee, VA 23801
Ft Gordon, GA 30905
Ft McClellan, AL 36201
Ft Knox, KY 40121
Ft Leonard Wood, MO 65473
Ft Sill, OK 73503
Ft Bliss, TX 79116
HQ, 1st Inf Div & Ft Riley, KS 66442
HQ, 5th Inf Div & Ft Polk, LA 71459
HQ, 7th Inf Div & Ft Ord, CA 93941

AF/RDXT
WASH DC 20330

AF/PREEU
Bolling AFB, DC 20332

AF Civil Engr Center/XRL
Tyndall AFB, FL 32401

Little Rock AFB
ATTN: 314/DEEE (Mr. Gillham)

US Naval Oceanographic Office
Code 1600-Library
WASH DC 20373

Naval Facilities Engr Command
ATTN: Code 04
Alexandria, VA 22332

Port Hueneme, CA 93043
ATTN: Library (Code L08A)
ATTN: Morrell Library

Washington, DC
ATTN: Building Research Advisory Board
ATTN: Transportation Research Board
ATTN: Library of Congress (2)
ATTN: Dept of Transportation Library

Defense Documentation Center (12)

Engineering Societies Library
New York, NY 10017

W. N. Lofroos, P. E.
Dept of Transportation
Tallahassee, FL 32304

Freeman, R E
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